POLITECNICO DI MILANO

Scuola di Ingegneria dei Sistemi

Polo territoriale di Como

Master of Science in
Management, Economics, and Industrial Engineering

A model for the supply chain representation and financial assessment

Supervisor: Prof. Alessandro PEREGO
Assistant supervisor: Dr. Paolo CATTI

Master graduation thesis by:
Luca Mattia GELSOMINO
Student Id: 759936

Academic Year: 2011/2012

Contents

List of Figures

List of Tables

Acknowledgments

I would like to thank the supervisor of this thesis, professor Alessandro Perego, for giving me the opportunity to carry out this thesis, as well as spend time and build experience within the *Osservatori* world.

I would also like to thank the co-supervisor, Paolo Catti, for his time, support, and extremely valuable advices throughout the whole developing process of this work.

I would also like to thank the team which I had the opportunity to work with during the model application phase: Christian Mondini and Chiara Borea.

Thus, I thank my family, for their invaluable support and encouragement during my entire university career: their never ending faith in me played a crucial role in this achievement; moreover, I thank my friends and classmates as well, the latter belonging to both the Bovisa and Como campuses.

Ultimately, I would like to thank Paola, for her huge support, comprehension, and advices, especially during the developing of this thesis. I am aware that she is accountable for a great deal of the successful outcome of this work.

Abstract

Widely-accepted models for the performance assessment of a supply chain (e.g.: SCOR) fail to take into account high-level, product-centric supply chains, defined as interconnected network of nodes constituted by groups of organizations. Nevertheless, this view of a supply chain, and a consequently methodology for its financial assessment, play a paramount role in the early stage of assessment of non-canonical financing solution, such as Supply Chain Finance (SCF) programs, that often exploit, among other factors, the strength of supply chain links.

Therefore, this work has as objective the development of a model for the supply chain representation and financial assessment. The model is based on academic contribution and empirical experience, gained through the profiling of two real-world supply chains; it is divided into three parts: the first presents a formal, graphical, representation of the supply chain, the second a tabular instrument highlighting relevant information regarding exchanges among nodes, while the third provides the financial assessment of each node, relatively to the whole supply chain.

The model is connected to the evaluation of SCF solutions. In particular, from its outcome is possible to deduct information to support the supply chain-level analyses often necessary in the evaluation of the application of SCF solutions to a supply chain. Such supply chain-specific information define the likelihood that organizations in a node will be suitable for specific sets of SCF solutions, as well as the roles that they may play in an SCF framework.

Ultimately, a web-based prototype based on this model has been developed. Its purpose is to show the expected implementation of the model in a tool. It collects the required inputs, inserted by the user, process them, and provides dynamic and interactive outputs. The prototype concludes the work and highlights its benefits, that are, the possibility of formally profiling a supply chain, with the purpose of its financial assessment, and to use the results of such assessment as support to the supply chain-level analyses, often required in the evaluation of the application of SCF solutions that benefit from the exploiting of the strength of supply chain links.

Executive Summary

Introduction and objectives

The last years have witnessed the growth of different sets of non-canonical financing solution for organizations. One of this sets, called Supply Chain Finance (SCF), is characterized by financing solutions that provide benefits to the parties involved through the exploitation of links and relationships among supply chain players. For this reason, the availability of a formal methodology for the financial assessment of an entire supply chain becomes critical. Therefore, the purpose of this thesis is to develop a model for the performing of such financial assessment, apt to its application within the analyses required for the application of SCF solutions to a supply chain.

Objectives

The objectives of this work can be effectively summarized in three research questions. Such questions compose the research framework of this work. The research framework is also represented in figure 1.

RQ 1. **The financial assessment of a supply chain**

- *What does it mean to financially assess a whole supply chain? How does this concept differs from the financial assessment of a single organization?*
- *What are possible choices of drivers that might suit the needs for the financial assessment of a supply chain?*

As showed in the literature review, the financial assessment of a supply chain is a concept that finds few academic contributions. Therefore, this question aims at developing a formal definition of financial assessment for a supply chain, providing a choice of measures and functions for the practical financial assessment of a supply chain.

RQ 2. **Financial assessment and supply chain profiling**

- *Are there more effective ways to represent a supply chain, in relation with its financial assessment?*
- *Is there a link between the representation methodology and the effectiveness of the financial assessment of a supply chain? Can a correct representation of a supply chain be part and parcel of its financial assessment?*

The supply chain profiling is a concept that finds application in many different topics, and benefit from an effective representation methodology. This question aims at inquiring if the financial assessment of a supply chain is affected by the way in which the supply chain is represented, and if a more effective way to represent it in relation with its financial assessment exists.

RQ 3. **Financial assessment and supply chain finance**

- *Are there links between the financial assessment of a supply chain and an effective application of financing solution, and in particular of non-canonical financing solution, such as solutions of Supply Chain Finance?*
- *How the different financial performance of supply chain nodes affects the implementation of non-canonical financing solutions?*

This third questions wishes to analyze the financial assessment methodology in terms of possible application of SCF solutions to a whole supply chain: possible roles for organizations within a specific node, areas of interest for particular sets of solutions, and, more in general, indications for effective implementations of those solutions based on the financial characteristics of the supply chain nodes. Moreover, it wants to analyze the differences in the application of SCF solutions to a whole supply chain, respect to a mere group of organizations.

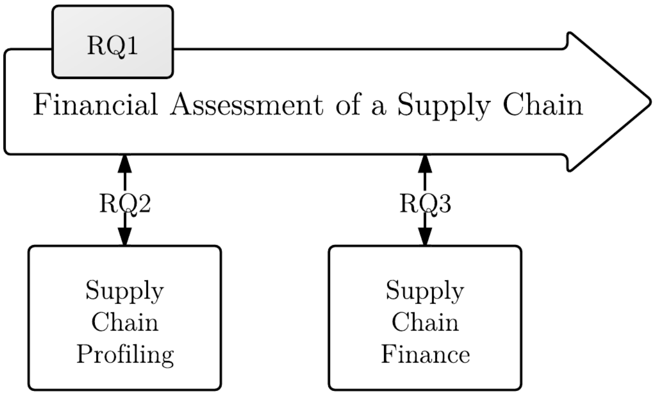


Figure 1: The research framework.

Literature review

The literature review provides the conceptual basis for this work, and consists in the critical evaluation of the most relevant academic contributions in all the topics constituting the research framework for the development of the model. Different typologies of contributions have been taken into account, namely:

- Journal articles, 42% of total contributions referenced in this work;
- Books or book chapters, 18%;
- Unpublished contributions (mainly conference proceedings and lecture notes), 16%;
- Technical reports, manuals, 16%;
- Patents, 4%;
- Other type of contributions, 4%.

On one side, the literature review has been focused on the determination of a shared definition of key concept (such as *supply chain* and *supply chain management*). Particular importance has been given to the study of the concept and of existing solutions of *supply chain finance*.

On the other side, it has been focused on the understanding of the current state of the models and methodologies developed for the representation and the financial assessment of a supply chain. In particular, major contributions in the development of methodologies, tools, and prototypes for the practical representation of a supply chain, as well as the most common commercial software have been inquired, together with the current models, methodologies, and set of measures used for the assessment of the financial performance of an entire supply chain.

Ultimately, the literature review has been focused on the context to which the model has been applied and tested: the Italian mechanical industry. In particular, this last part provides an initial, more formal, understanding of the supply chain used to test the model, as well as a basis to structure the analyses of secondary sources.

Methodology

The methodology followed in this work is reported in figure 2.

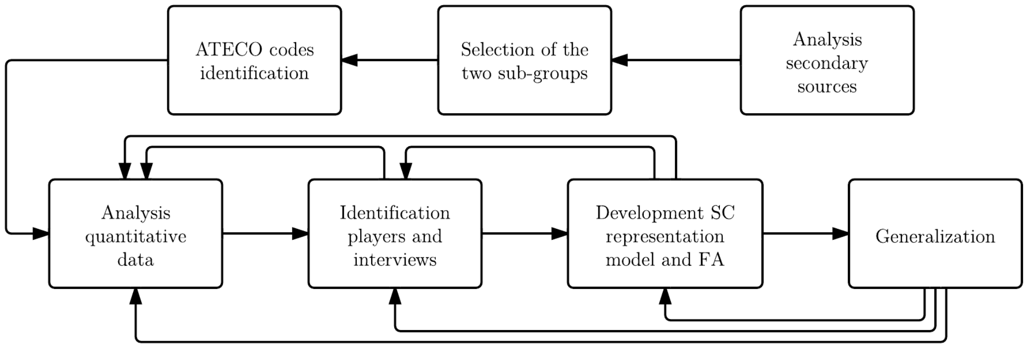


Figure 2: The recursive steps of the methodology followed in the development of this work.

An initial analysis of secondary sources brought to the selection of the two supply chains that have served as empirical base for the model development and application (namely, the manufacture of tubes and the manufacture of machinery for the food industry supply chains); once selected the two sub-groups, a series of ATECO[1] codes, representing the possible nodes of the supply chain, have been identified. These initial steps brought the required analyses for the development of the model; such analyses can be divided into two groups:

- Quantitative analyses: related to the preparation, exploration, and utilization of data downloaded from the AIDA on-line database. The queries through which the data have been downloaded are based on the ATECO code selected at the beginning of the work; later in the work it was necessary to add nodes to the supply chain that were not reliably identifiable through an ATECO code; for such node, the query has been based on the business name lists provided by Bilanci d'acciaio [2011]. In the end, a total of around 18.000 balance sheets and income statements have been analyzed, and represent the source from which the data in the model application chapter are based;
- Qualitative analyses: related to the gather and analyses of secondary sources, including technical reports and interviews. In particular, the purpose of the interviews has been to gather the necessary information for building a reliable understanding of the supply chains object of the model applications. The body of knowledge built comprehends 29 interviews, of which 18 to practitioners, and the remaining to experts, professors, and industry associations.

The application of the model has been concurrent with its development. After a first application to the two selected supply chains, the recursive process adopted have refined progressively the model generalizing it.

Model description

The model developed is divided into three parts. The first part, called *Supply Chain Flowchart*, is a graphical representation of the supply chain through basic flowcharting components. The second part provides the structural matrices, called *node exchanges matrix* and *production coefficients matrix*, that summarize the structure of the exchanges among players. The third output is the financial assessment of the supply chain, and provides a series of radar charts, correlated with a scatter plot from which is possible to highlight relevant information about the supply chain nodes; this last part provides also information that can be used to assess the possibility of effectively apply non-canonical financing solution (and in particular Supply Chain Finance solutions) to the supply chain.

[1]ATECO is the Italian system of classification of economic activities, which high-level codes correspond to the international NACE.

Supply Chain Flowchart

Figure 3 reports the first output of the model for the manufacture of tube supply chain.

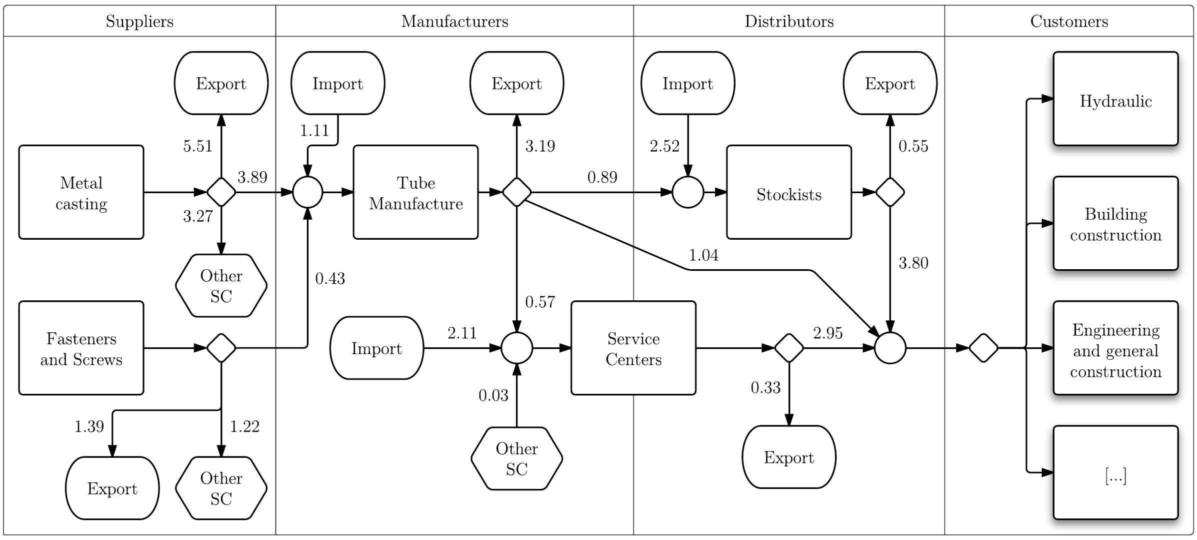


Figure 3: The supply chain flowchart for the manufacture of tube supply chain.

Such representation concentrates relevant information about the structure of the supply chain nodes and arc. It is divided in four *swim-lanes*, that categorize the nodes in suppliers, manufacturers (the *focal point* of the representation), distributors, and customers. This model output presents innovative characteristics in the formality through which it defines the representation methodology, and in the orientation of the representation to the financial assessment of the supply chain. The unification of different components, traditionally not present under a single representation methodology, and its capacity of directly and indirectly affecting the financial assessment of the supply chain bring a component of innovation to the representation methodology proposed. Furthermore, the formality of the methodology (including the definition of an ontology at the base of the model) represents an innovative contribution for the representation methodologies based on a concept of supply chain composed by nodes represents groups of organizations, compared to the more common, organizational-centric, supply chain.

Structural matrices

The second output of the model is represented by the node exchanges and production coefficients matrices. These two matrices summarize in a tabular form structure and value of the exchanges among supply chain nodes. The first matrix, which application to the supply chain object of this work is reported in table 1, shows the value of the exchanges among nodes (i.e.: the value of the arcs); such representation allows a quick visualization of the value and structure of exchanges between a node and every single other node, as well as between a node and the entire supply chain. Table 5 at page 10 provides the legend for the name of nodes in figure and table of this section.

The second matrix, the *production coefficients matrix*, is reported in table 2. Such matrix contains the *production coefficients*, that represents, for a generic node i, how many euro of output must flow from a generic node to i, in order for it to produce one euro of output.

The production coefficients matrix gives several indications on the structure of dependences and links among nodes in the supply chain. The values, deviation, and distribution of the coefficients allow to understand how strong supply chain links are, in terms of economic value exchanged. Moreover, the total value of each column describes the dependencies of a node from its suppliers; being the coefficients estimable also for the import row, they can be used to compare the node dependencies from national and abroad production. An uniform distribution of the coefficients, and a low total value, represents a node that relies relatively little on raw materials and more on internal transformation (cf.: G6 in table 2 and 1), while a single, high, coefficient represents a node that relies strongly on the output produced by one of its suppliers (note that this may, as may not, imply the vice versa).

from $i \downarrow$ to $j \rightarrow$	G6	G9	G10	G11	Export	Other SC	Customers	Total
G1	0.20	-	-	-	7.87	1.53	-	9.60
G2	0.11	-	-	-	5.08	0.37	-	5.57
G3	0.15	-	-	-	3.22	4.08	-	7.46
G4	0.18	-	-	-	0.00	26.59	-	26.77
G5	0.28	-	-	-	2.80	10.58	-	13.66
G6	-	-	-	-	2.25	-	1.65	3.90
G7	0.19	3.89	-	-	5.51	3.27	-	12.85
G8	0.06	0.43	-	-	1.39	1.16	-	3.04
G9	0.05	-	0.57	0.98	3.19	-	0.99	5.78
G10	0.03	-	-	-	0.33	-	2.95	3.30
G11	0.05	-	-	-	0.55	-	3.80	4.40
Other SC	0.33	-	0.03	-	-	-	-	0.35
Imports	0.29	1.11	2.11	2.52	-	-	-	26.19
Total	1.92	5.43	2.71	3.50	32.19	47.58	9.39	

Table 1: Node exchanges matrix for the supply chain object of this work (bln €).

from $i \downarrow$ to $j \rightarrow$	G6	G9	G10	G11
G1	0.05	-	-	-
G2	0.03	-	-	-
G3	0.04	-	-	-
G4	0.05	-	-	-
G5	0.07	-	-	-
G6	-	-	-	-
G7	0.05	0.67	-	-
G8	0.01	0.07	-	-
G9	0.01	-	0.17	0.22
G10	0.01	-	-	-
G11	0.01	-	-	-
Other SC	0.08	-	0.01	-
Import	0.07	0.19	0.64	0.57
Total	0.48	0.93	0.82	0.79
Ones' complement	0.52	0.07	0.18	0.21

Table 2: Production coefficients matrix for the supply chain object of this work.

Financial Assessment of a Supply Chain

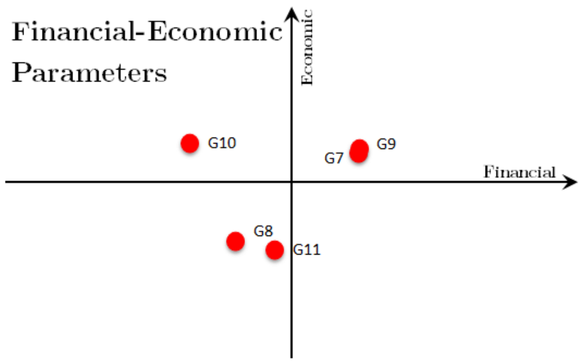
The third part of the model, the financial assessment methodology, assesses financially each node, in relation to the whole supply chain. The assessment is based on the analytic estimation of four parameters, summarized in table 3. Three measures are assigned to each parameter, for a total of twelve measures.

The three measures, estimated for each node, are normalize with respect to the other nodes, and positioned on two six-axes radar charts (the first with parameters F and E, the second with parameters N and P). Such radar charts are useful to compare the profile of different nodes, and give a first insight on the strength and weaknesses of each node, in relation to the other nodes of the supply chain. The set of radar charts for the manufacture of tubes supply chain is reported in figure 5.

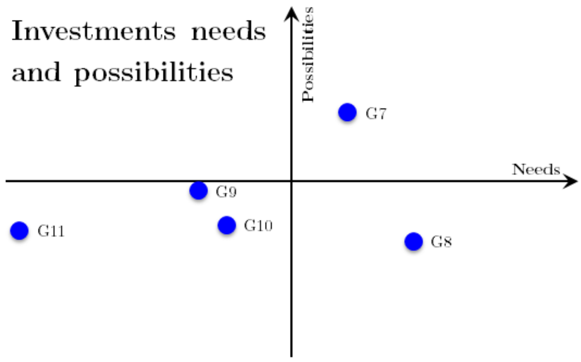
Once the four parameters have been estimated, through the application of the appropriate function, they are placed on two scatter plots, the first in the space (F, E), the second in the space (P, N). Such scatter plots can be overlapped, and the points referring to the same node connected, creating segments. The process, applied to the manufacture of tube supply chain, is reported in figure 4.

Parameter	Description	Measures
Financial (F)	Ability to manage cash flows	Days of receivables, Days of inventories, Days of payables
Economic (E)	Ability to generate profit	EBITDA, EBIT, ROS
Investment Possibilities (P)	Possibility of increase debt through canonical financing solutions	Leverage, Financial Charges over EBITDA, Net Financial Position
Investment Needs (N)	Necessity of increase debt to financing investment (especially in tangible assets)	Depreciation and Amortization over Total Asset, percentage increase of tangible assets, Asset Turnover

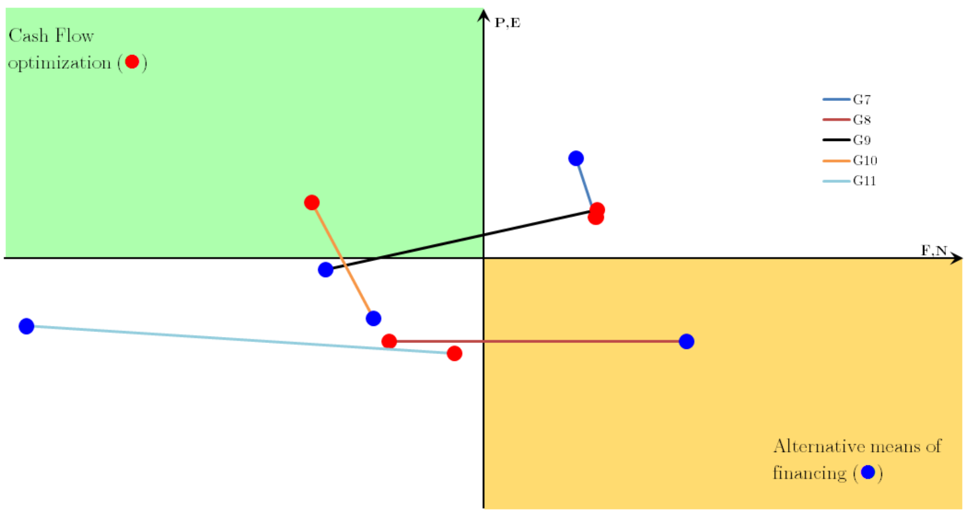
Table 3: Parameters for the financial assessment of a supply chain, and relative measures.



(a) Financial-Economic parameters



(b) Investment needs and possibilities parameters



(c) Financial assessment matrix

Figure 4: The financial assessment matrix and the two scatter plots from which it derives.

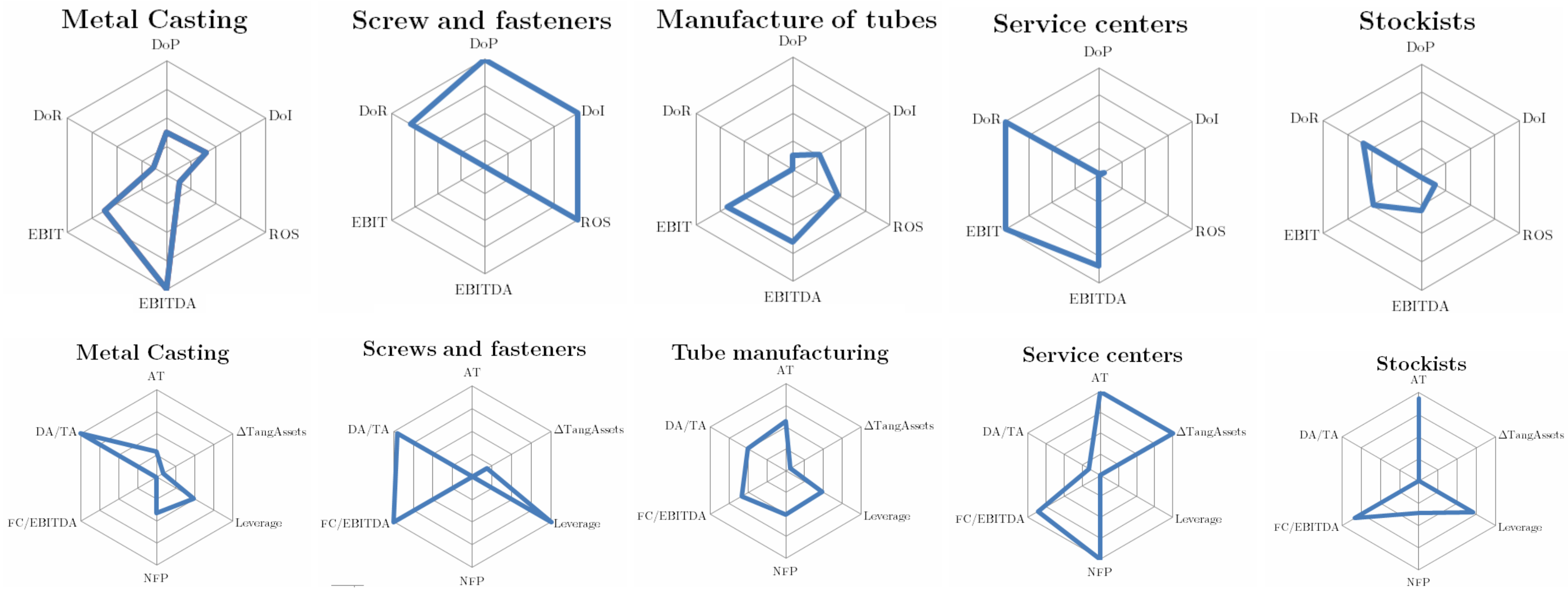


Figure 5: Radar charts for the tube manufacture supply chain.

Assessment of non-canonical financing solutions

The financial assessment of a supply chain has a clear implication in the evaluation of non-canonical financing solutions, in particular, of solutions of *Supply Chain Finance* (SCF). Such solutions, exploiting the links among parties belonging to a supply chain, increase the value[2] of the organizations involved providing means of financing apt to optimize the cash to cash cycle and the $WACC$.

For the practice purpose of interpreting the result of the financial assessment methodology, SCF solutions can clustering in two groups: the first, called Cash Flow Optimization (CFO), contains solutions apt at optimizing the cash to cash cycle of organizations involved; the second, called Alternative Means of Financing (AMF), containing solutions apt at providing to organizations competitive alternative means of financing that exploit the strength of the links among two players in a supply chain.

Taking as a reference the chart reported in figure 4(c), it can be noticed that, considering the quadrants only and not the specific coordinates, there are sixteen different possible segments (eight segments, twice two, considering that orientation matters). Such sixteen segments can be grouped in nine clusters. The nine clusters present characteristics that indicate the likelihood of organizations belonging to the analyzed node to benefit from the application of an SCF solution to the supply chain, as well as the likelihood of organizations to have a role in an SCF framework. The nine clusters are described in table 4.

Cluster	Logic expression[1]	Description
1 High performer	$F \wedge E \wedge P \wedge N$	The node presents high level of each parameter, and is considered a strong performer.
2 Cash provider	$F \wedge E \wedge P \wedge \neg N$	The node is an high performer who has (in relative terms) possibilities of increase debt higher respect to its needs ($P > N$); organizations in this node are likely to be *cash providers*.
3 AMF	$F \wedge E \wedge \neg P \wedge N$	The node shows high investment needs, but low possibilities; it is likely to benefit from SCF solutions called alternative means of financing, exploiting the links with other supply chain players able to provide them debt at a lower cost (e.g.: those in cluster 2).
4 Doubtful case	$(F \wedge E \wedge \neg P \wedge \neg N) \vee (\neg F \wedge \neg E \wedge P \wedge N)$	The cluster contains the cases for which it is difficult to draw conclusions related to possible financing solutions. Specific and more detailed analyses are usually required.
5 Low performer	$\neg E \wedge (\neg F \vee \neg N \vee P) \wedge (F \wedge N \vee \neg P)$	The node presents weak performance in generating profit and in one or more other parameters. It is likely that such performance cannot be improved through the sole application of an SCF solution.
6 Possible AMF	$\neg E \wedge F \wedge \neg P \wedge N$	This node shares similar characteristics respect to node in cluster 3, but its low profit generation performance weaken its suitability for AMF solutions.
7 CFO	$E \wedge \neg F \wedge (P \vee \neg N)$	This node is strong in profit generation, but weak in managing cash flows: it is suitable to SCF solutions of cash flow optimization.
8 SCF needy	$E \wedge \neg F \wedge \neg P \wedge N$	Sharing both characteristics of both cluster 3 and 7, node in this cluster presents the needs for both the typologies of SCF solution proposed.
9 Potential cash provider	$\neg E \wedge P \wedge \neg N$	With characteristics similar to cluster 2, nodes in this cluster are less likely than them to be cash provider, given their weak economic performance.

[1] A parameter is true if > 0, false otherwise. Convention: AND $\rightarrow \wedge$, OR $\rightarrow \vee$, negation $\rightarrow \neg$.

Table 4: The nine identified clusters.

[2] Defined as: $V(0) = \sum_{t=0}^{\infty} \frac{NCF(t)}{(1+WACC)^t}$

The combined presence of nodes belonging to different clusters shapes the possible financing solution that can have a positive effect on organizations within the supply chain. For example, the presence of nodes in cluster 2 (cash providers), and in cluster 3 (AMF), draws a context in which the latter may benefit from an alternative mean of financing provided by the former, e.g.: organizations in cluster 2 can likely have an interest rate i_2, while the ones in cluster 3 an interest rate i_3; the former can provide to the latter debt at an interest $i_k \Leftrightarrow i_2 < i_k < i_3$ beneficial for both of them.

The interpretation of the segments cannot exempt from the contextual interpretation of the messages coming from the other outputs of the model. If an SCF solution requires the presence of a link among two nodes, such link should be inquired not only in terms of *quality* of the relationships among parties, but also in quantitative terms: a node that relies entirely, or almost entirely, from abroad production, is less likely to have the necessary strength for an SCF solution involving its national suppliers. In the same way, if a node requires a solution of cash flow optimization, such solution is likely to be more beneficial if it involves the more relevant supplier node in terms of value exchanged. Such considerations can be drawn from the first two outputs of the model.

Prototype

After the definition of the model, a web-based prototype has been developed. Such prototype has the purpose of show the model outputs in a dynamical and interactive way. This allow to highlight features that are difficult to highlight in a written document, and to provide insights in the desired, practical, usage of the model.

The prototype is available at the url `http://supplychain.altervista.org`. It allows a user without deep knowledge about the topic of this work, to assess financially a supply chain, and to gather insights on the possible application of SCF solution in the provided supply chain. The user is required to input basic information about the supply chain (no. of nodes, value of arcs and of indicators), and the prototype provides the desired three outputs of the model. The objective of the prototype is to show the possible integration of the model within a *tool*; in fact, being part of a tool, the model can be practically used and inserted in the flow of the analyses required for the assessment of the application of SCF solution to a supply chain, where it can enhance the quality of the first, unavoidable, supply chain-level analysis.

Model application and testing

The model has been applied to two Italian supply chains: the manufacture of tube, and the manufacture of machinery for the food industry supply chain. The application provided an empirical base for testing the developed model. The test has been based on the comparison of messages about the supply chains gathered through the analyses of secondary sources and interviews, and the messages provided by the model application. Most of the messages identified in the model output have found a parallel in the ones gathered through the secondary sources, and vice versa. In particular, some of that are:

- The service centers node (within the distribution tier of the manufacture of tube supply chain) belongs to cluster 7 (Cash Flow Optimization), given its good profit generation and weak cash flow management performances. This is confirmed by the analyses of secondary sources, that highlights the difficulties of the service centers in dealing with the upstream nodes, that have more bargaining power;

- The stockists node (belonging to the same tier of the service centers) present a weak performance (cluster 5), confirmed by the analyses of secondary sources. They suffer the same criticality of the service center, worsened by the lack of possibility of customize products to met the demands of specific customers (like the service centers); this factor, likely, affected their ability to generate profit;

- The production coefficient matrix for the machinery for the food industry highlights how they do not rely strongly on any of the numerous suppliers, as gathered through the interviews and the analyses of secondary sources.

Conclusions and future researches

The model developed in this thesis addresses the need for a comprehensive methodology for the financial assessment of a supply chain. Such methodology relies on a standardized representation of the supply chain, that through graphical and tabular instruments highlights the structure of the supply chain, as well as strength and dependencies in the links between its nodes. The methodology for the financial assessment generate an output that represent the assessment of each single node, in relation to the whole supply chain. Such output has been found to provide insights about the implementation of SCF solutions to the supply chain. In particular, the model outputs can be used to assess if organizations within a node will benefit from the application of an SCF solution, as well as if they are suitable to play specific roles within an SCF framework.

The model has been implemented in a prototype[3], with the purpose of highlight how the model can be used as a practical instrument within the necessary analyses for the implementation of SCF solution to a supply chain. Such practical use present different managerial implications: a correct implementation and usage of the tool can be beneficial for financial institutions, industry associations, and single organizations, especially within the analyses for the assessment of the benefit of an SCF solution; in fact, a player willing to analyze the benefits of an SCF solution, often cannot avoid a first analysis at the supply chain level, that can be carried out with the proper application of the present model.

Future recommendations include:

- Modification of the model structure and further validation, included further application of the model for testing purposes: test of different sets of measures respect to the ones proposed, test with non-financial indicators, application of the model to non-manufacturing supply chains;
- Modification related to the topic of Supply Chain Finance, included the consideration of less-known SCF solutions, as well as the updating of the model with new, innovative, sets of SCF solutions. Moreover, the model can be modified to include a quantitative assessment of benefits of specific SCF solutions for the supply chain object of the analysis;
- Inquiring the relationships between the correct implementation of ICT practices (e.g.: an ePayable system) in the supply chain and the outcome of the financial assessment methodology, as well as the likelihood that such practices have on the application of SCF in the supply chain;
- Improvement to the prototype, till an eventual development of a software for the financial assessment of the supply chain, that includes the analyses required to assess the benefit of an SCF solution.

ID	Extended name
G1	Engines
G2	Taps and valves
G3	Gearings
G4	General mechanical engineering
G5	Metal structures
G6	Machinery for the food industry
G7	Metal casting
G8	Screws and fasteners
G9	Tube manufacturing
G10	Service center - tubes
G11	Stockists - tubes

Table 5: Legend for tables and figures in this executive summary.

[3]Available at `http://supplychain.altervista.org`.

Sommario

Introduzione ed obiettivi

Gli ultimi anni hanno mostrato una tendenza alla crescita di soluzioni non canoniche di finanziamento per le imprese. Un sottoinsieme di tali soluzioni, dette soluzioni di *Supply Chain Finance* (SCF), contiene soluzioni che generano benefici per le parti coinvolte attraverso lo sfruttamento delle relazioni all'interno della supply chain. Per questa ragione, è quindi critica la necessità di una metodologia formale per la stima dello stato di salute di un'intera supply chain. L'obiettivo alla base di questa tesi è quindi la definizione di tale metodologia, orientata a fornire uno strumento utile nelle fasi iniziali dell'analisi dell'applicazione di soluzioni di SCF.

Obiettivi

Gli obiettivi di questo lavoro possono essere efficacemente riassunti in tre domande di ricerca. Tali domande compongono il quadro di riferimento di questo lavoro. Tale quadro è rappresentato graficamente in figura 6

DdR 1. **Lo stato di salute di una supply chain**

- *Che cosa significa stimare lo stato di salute di una supply chain? Come differisce tale concetto dalla stima per una singola organizzazione*
- *Quali sono le possibili scelte di misure che possono essere utilizzate per la stima dello stato di salute di una supply chain?*

Come mostrato nell'analisi della letteratura, la stima dello stato di salute di una supply chain è un concetto che trova scarsi contributi. Quindi, questa domanda di ricerca è mirata allo sviluppo di una definizione formale di stima dello stato di salute per una supply chain, fornendo contestualmente una scelta di misure e funzioni per la stimare praticamente tale stato per una supply chain.

DdR 2. **Stato di salute e rappresentazione della supply chain**

- *Ci sono modi efficienti per rappresentare una supply chain in relazione con il suo stato di salute?*
- *Ci sono legami tra la metodologia rappresentativa e l'efficacia della stima dello stato di salute di una supply chain? Può una corretta metodologia rappresentativa essere parte integrante della stima dello stato di salute?*

La rappresentazione di una supply chain è un concetto che trova applicazioni in svariati argomenti. Questa domanda mira a indagare se la stima dello stato di salute di una supply chain è influenzato dal modo in cui tale supply chain è rappresentata, e se esistono metodi più efficaci per rappresentarla in relazione a tale stima.

DdR 3. **Stato di salute e Supply Chain Finance**

- *Ci sono legami tra la stima dello stato di salute ed una effettiva applicazione di soluzioni di finanziamento, ed in particolare di soluzioni non-canoniche come quelle di Supply Chain Finance?*

- *In che modo lo stato di salute dei nodi che compongono la supply chain influenza l'applicazione di soluzioni non canoniche di finanziamento?*

Questa terza domanda di ricerca si pone l'obiettivo di analizzare la metodologia di stima dello stato di salute in termini di possibili applicazioni di soluzioni di SCF ad un'intera supply chain, nonché indicazioni basate sullo stato di salute dei nodi utili per una implementazione efficace di tali soluzioni. Inoltre, tale domanda indaga le differenze nell'applicazione di soluzioni di SCF ad un intera supply chain, respetto che ad un generico gruppo di organizzazioni.

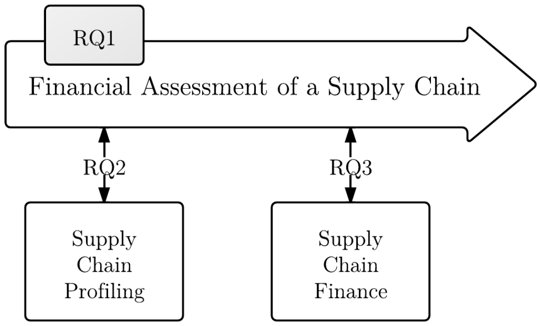


Figure 6: Il quadro di riferimento di questa tesi.

Analisi della letteratura

L'analisi della letterature costituisce la base concettuale di questo lavoro, e consiste nella valutazione critica dei contributi più rilevanti riguardanti gli argomenti che costituiscono il quadro di riferimento per questo lavoro. Diverse tipologie di contributi sono stati presi in considerazione:

- Articoli scientifici, per il 42% dei contributi;
- Libri di testo, 18%;
- Contributi non pubblicati (atti di convegni e lezioni), 16%;
- Manuali, *report* di osservatori 16%;
- Brevetti, 4%;
- Altre tipologie, 4%.

Da un lato, l'analisi si è concentrata sulla definizione di concetti chiave per il lavoro (quali quelli di *supply chain* o *supply chain management*), dando particolare importanza allo studio del concetto e delle soluzioni esistenti di *supply chain finance*.

Dall'altro lato, è stato approfondito lo studio dei modelli e delle metodologie esistenti per la rappresentazione e la stima dello stato di salute di una supply chain. Nello specifico, sono stati analizzati i principali contributi in termini di metodologie, strumenti e prototipi per la rappresentazione pratica di una supply chain, così come sono stati analizzati i principali software presenti sul mercato; allo stesso modo sono stati analizzati i modelli, le metodologie, e gli insiemi di misure utilizzati per la valutazione della performance finanziaria di un'intera supply chain.

Infine, la letterature si è focalizzata sul contesto di applicazione e test del modello: l'industria meccanica italiana. In particolare, la parte conclusiva del capitolo presenta un quadro iniziale, formale, della supply chain usata per testare il modello, così come le basi su cui è stata strutturata l'analisi delle fonti secondarie.

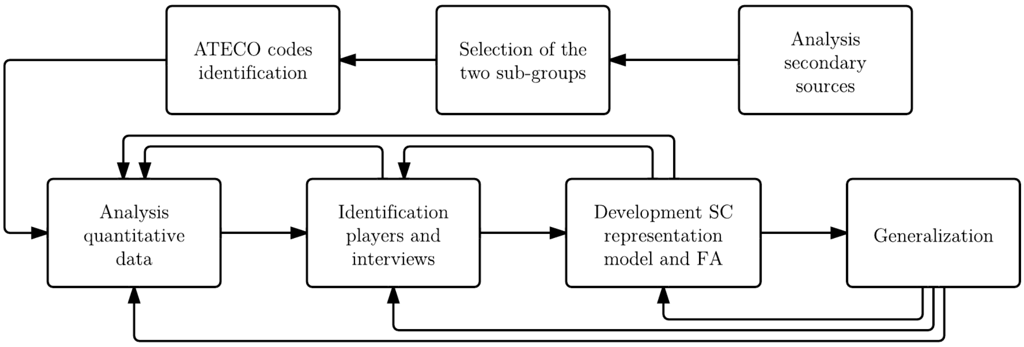


Figure 7: I passi metodologici ricorsivi utilizzati nello sviluppo del modello.

Metodologia

La metodologia utilizzata in questo lavoro è riportata in figura 7.

Un iniziale analisi delle fonti secondarie ha portato alla selezione delle due supply chain che sono state utilizzate come base empirica per questo lavoro (ossia: la fabbricazione di tubi e la fabbricazione di macchine per l'industria alimentare); una volta selezionati i due ambiti di applicazione, una serie di codici ATECO[4], rappresentanti i possibili nodi della supply chain, sono stati selezionati. Da questi passi iniziali è stato possibile procedere con le analisi, che possono essere suddivise in due gruppi:

- Analisi quantitative: preparazione, esplorazione ed effettivo utilizzo dei dati scaricati dal database online AIDA. I dati sono stati scaricati attraverso delle opportune interrogazioni basate sui codici ATECO selezionati precedentemente; nelle fasi successive del lavoro è stato necessario aggiungere dei nodi della supply chain che non potevano essere identificati in modo chiaro attraverso un codice ATECO; per questi nodi, le interrogazioni sono state basate sulla lista delle ragioni sociali prodotta da Bilanci d'acciaio [2011]. In sostanza, sono stati analizzati circa 18.000 stati patrimoniali e conti economici, che rappresentano la base per i valori numerici presentati nel capitolo di applicazione del modello;

- Analisi qualitative: raccolta ed analisi di fonti secondarie, inclusi rapporti di osservatori ed interviste. In particolare, l'obiettivo delle interviste è stato quello di raccogliere le necessarie informazioni per comprendere e analizzare la struttura delle due supply chain oggetto dell'applicazione del modello. Sono state effettuate 29 interviste, di cui 18 ad imprese, e le rimanenti a esperti, professori, e associazioni di filiera.

L'applicazione del modello è stata condotta in parallelo con lo sviluppo del modello stesso. Dopo una prima applicazione alle due supply chain selezionate, il processo ricorsivo adottato ha rifinito il modello attraverso un processo di generalizzazione e successive applicazioni.

Descrizione del modello

Il modello oggetto di questa tesi è diviso in tre parti. La prima, chiamata *Supply Chain Flowchart*, è una rappresentazione grafica della supply chain che utilizza dei componenti classici dei diagrammi di flusso. La seconda parte fornisce invece due *matrici strutturali*, chiamate *node exchanges matrix* e *production coefficients matrix*, che sintetizzano la struttura degli scambi tra i diversi nodi. La terza parte rappresenta la stima dello stato di salute della supply chain, e produce una serie di grafici radar e piani cartesiani da cui è possibile evidenziare informazioni rilevanti sui nodi della supply chain: questa terza parte è anche legata alla valutazione della possibilità di applicare una soluzione di finanziamento non canonica (in particolare una soluzione di SCF) alla supply chain.

[4]La nomenclatura ATECO è il sistema italiano di classificazione delle attività economiche, equivalente (ad alti livelli di codici) al sistema internazionale NACE.

Il Supply Chain Flowchart

In figura 8 è riportato il risultato della prima parte del modello per la supply chain della fabbricazione di tubi.

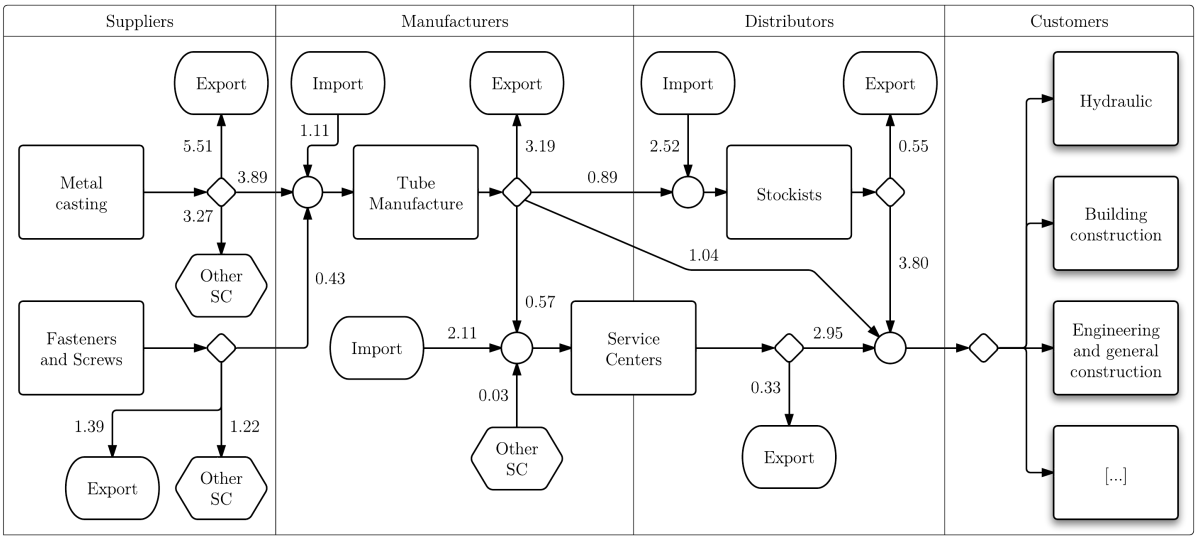


Figure 8: Il Supply Chain Flowchart per la supply chain della fabbricazione di tubi.

Tale rappresentazione racchiude le principali informazioni sulla struttura dei nodi e degli archi della supply chain. Essa è divisa in quattro *corsie*, che categorizzano i nodi in *suppliers*, *manufacturers* (nodi focali della rappresentazione), *distributors*, e *customers*. Tale rappresentazione racchiude caratteristiche innovative nella formalità con cui è definita la metodologia sviluppata, e nel suo orientamento alla stima dello stato di salute di una supply chain. L'insieme di diversi componenti, comunemente non presenti sotto una stessa metodologia rappresentativa, e la capacità di influenzare direttamente e indirettamente la stima dello stato di salute di una supply chain rappresenta l'innovatività di questa parte di modello. Inoltre, la formalità della metodologia (che è basata sulla definizione di un'ontologia), rappresenta un contributo innovativo nel quadro delle metodologie di rappresentazione di quelle supply chain composte da nodi rappresentanti gruppi di organizzazioni, in contrapposizione con la più tradizionale, impresa-centrica, supply chain.

Matrici strutturali

La seconda parte del modello è costituita dalle matrici *node exchanges* e *production coefficients*. Tali matrici sintetizzano in forma tabulare la struttura ed il valore degli scambi tra i nodi della supply chain. La prima matrice, la cui applicazione alla supply chain oggetto di questa tesi è riportata in tabella 6, presenta il valore degli scambi tra i nodi (ossia: il valore degli archi); tale rappresentazione permette una rapida visualizzazione del valore e della struttura di tali scambi tra un nodo ed ogni altro nodo della supply chain, così come tra un nodo e il resto della supply chain. La tabella 10, a pagina 20, fornisce la legenda delle sigle dei nodi riportate nelle tabelle e figure di questa sezione.

La seconda matrice, detta *production coefficients*, è riportata in tabella 7. Tale matrice contiene i coefficienti di produzione, che rappresentano, per un generico nodo i, quanti euro di produzione devono provenire da ogni altro nodo della supply chain ad i, in modo tale che egli possa generare un euro di produzione.

La matrice *production coefficients* fornisce diverse indicazioni sulla struttura delle dipendenze e legami tra nodi della supply chain. I valori, deviazione e distribuzione dei coefficienti permettono di capire la forza dei legami della supply chain, in termini di valore economico scambiato. Inoltre, il valore totale di ogni colonna descrive le dipendenze di un nodo da i suoi fornitori; poiché il coefficiente di produzione può essere stimato anche per il nodo delle importazioni, la matrice può essere usata per comparare le dipendenze di un nodo dalla produzione nazionale ed internazionale. Una distribuzione uniforme dei coefficienti, ed un valore totale basso, rappresentano un nodo che fa affidamento più sulla trasformazione

da $i \downarrow$ a $j \rightarrow$	G6	G9	G10	G11	Export	Other SC	Customers	Total
G1	0.20	-	-	-	7.87	1.53	-	9.60
G2	0.11	-	-	-	5.08	0.37	-	5.57
G3	0.15	-	-	-	3.22	4.08	-	7.46
G4	0.18	-	-	-	0.00	26.59	-	26.77
G5	0.28	-	-	-	2.80	10.58	-	13.66
G6	-	-	-	-	2.25	-	1.65	3.90
G7	0.19	3.89	-	-	5.51	3.27	-	12.85
G8	0.06	0.43	-	-	1.39	1.16	-	3.04
G9	0.05	-	0.57	0.98	3.19	-	0.99	5.78
G10	0.03	-	-	-	0.33	-	2.95	3.30
G11	0.05	-	-	-	0.55	-	3.80	4.40
Other SC	0.33	-	0.03	-	-	-	-	0.35
Imports	0.29	1.11	2.11	2.52	-	-	-	26.19
Totale	1.92	5.43	2.71	3.50	32.19	47.58	9.39	

Table 6: La matrice *node exchanges* per la supply chain oggetto di questa tesi (mld €).

da $i \downarrow$ a $j \rightarrow$	G6	G9	G10	G11
G1	0.05	-	-	-
G2	0.03	-	-	-
G3	0.04	-	-	-
G4	0.05	-	-	-
G5	0.07	-	-	-
G6	-	-	-	-
G7	0.05	0.67	-	-
G8	0.01	0.07	-	-
G9	0.01	-	0.17	0.22
G10	0.01	-	-	-
G11	0.01	-	-	-
Other SC	0.08	-	0.01	-
Import	0.07	0.19	0.64	0.57
Totale	0.48	0.93	0.82	0.79
Complemento ad uno	0.52	0.07	0.18	0.21

Table 7: La matrice *production coefficients* per la supply chain oggetto di questa tesi.

interna che sulle materie prime (cf.: gruppo G6, tabelle 7 e 6), mentre un singolo, alto, coefficiente rappresenta un nodo che fa affidamento su un solo singolo nodo per la fornitura di materie prime.

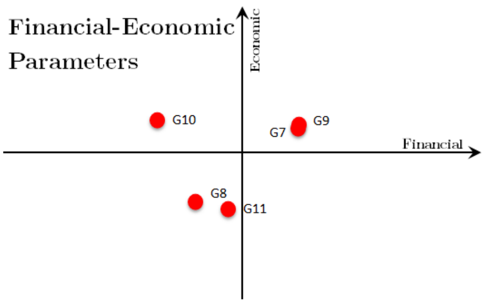
Stima dello stato di salute di una supply chain

La terza parte del modello, la stima dello stato di salute della supply chain, stima tale stato per ogni nodo, in relazione all'intera supply chain. La metodologia è basata sulla stima analitica di quattro parametri, riassunti nella tabella 8. Per ogni parametro, sono state identificate tre misure, per un totale di dodici misure. Tali tre misure, calcolate per ogni nodo, sono normalizzate rispetto agli altri nodi, e posizionate su due grafici radar da sei assi l'uno (il primo grafico con le misure relative ai parametri F e E, il secondo con quelle relative ai parametri N e P). Tali grafici sono utili per confrontare i diversi profili dei nodi, e forniscono una prima serie di intuizioni sui punti di forza e debolezza di ogni nodo, in relazione agli altri nodi della supply chain. L'insieme dei grafici radar per la supply chain della fabbricazione dei tubi è riportato in figura 10.

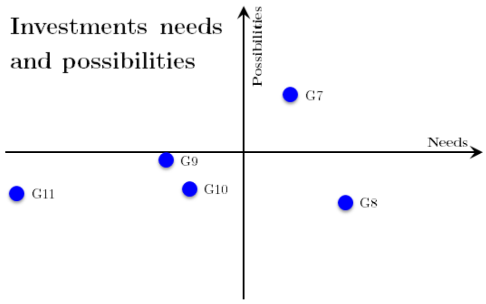
Una volta che sono stati stimati i quattro parametri (per ogni nodo), attraverso l'applicazione di una funzione atta allo scopo essi possono essere posizionati su due piani cartesiani, il primo nello spazio (F, E), il secondo nello spazio (P, N). Tali piani cartesiani possono essere sovrapposti, e i punti relativi allo stesso nodo collegati, creando così una serie di segmenti. Il processo, relativo alla supply chain della fabbricazione di tubi, è riportato in figura 9.

Parametro	Descrizione	Misure
Finanziario (F)	Gestire flussi di cassa	Durata media crediti, durata media debiti, durata media giacenza
Economico (E)	Generare profitti	EBITDA, EBIT, ROS
Possibilità investimento (P)	Aumentare debito canonicamente	Leva, oneri fin. su EBITDA, posizione finanziaria netta
Necessità investimento (N)	Necessità aumentare debito per investimenti (specialmente in IIM)	Ammortamenti su attivo, incremento IIM, Asset Turnover

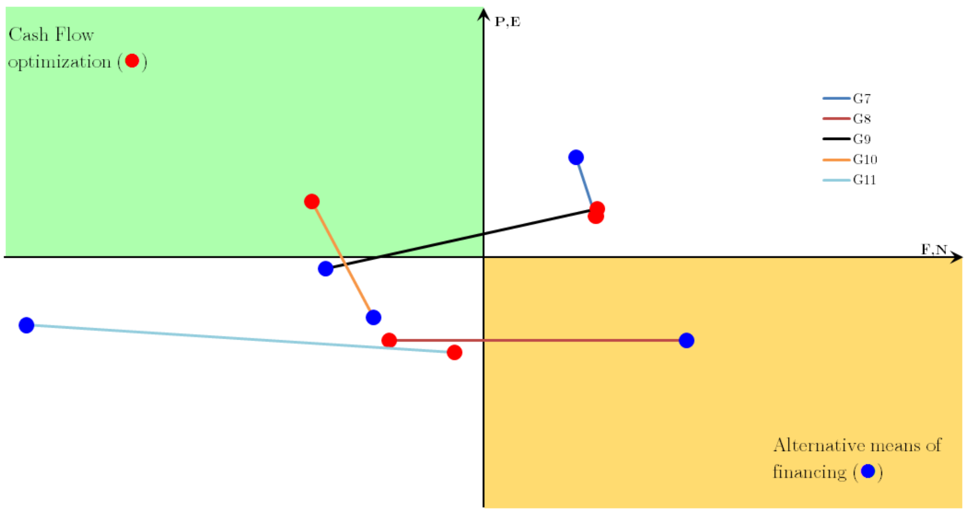
Table 8: Parametri e misure per la stima dello stato di salute di una supply chain.



(a) Financial-Economic parameters



(b) Investment needs and possibilities parameters



(c) Financial assessment matrix

Figure 9: Il piano cartesiano per la stima dello stato di salute e i due piani da cui deriva.

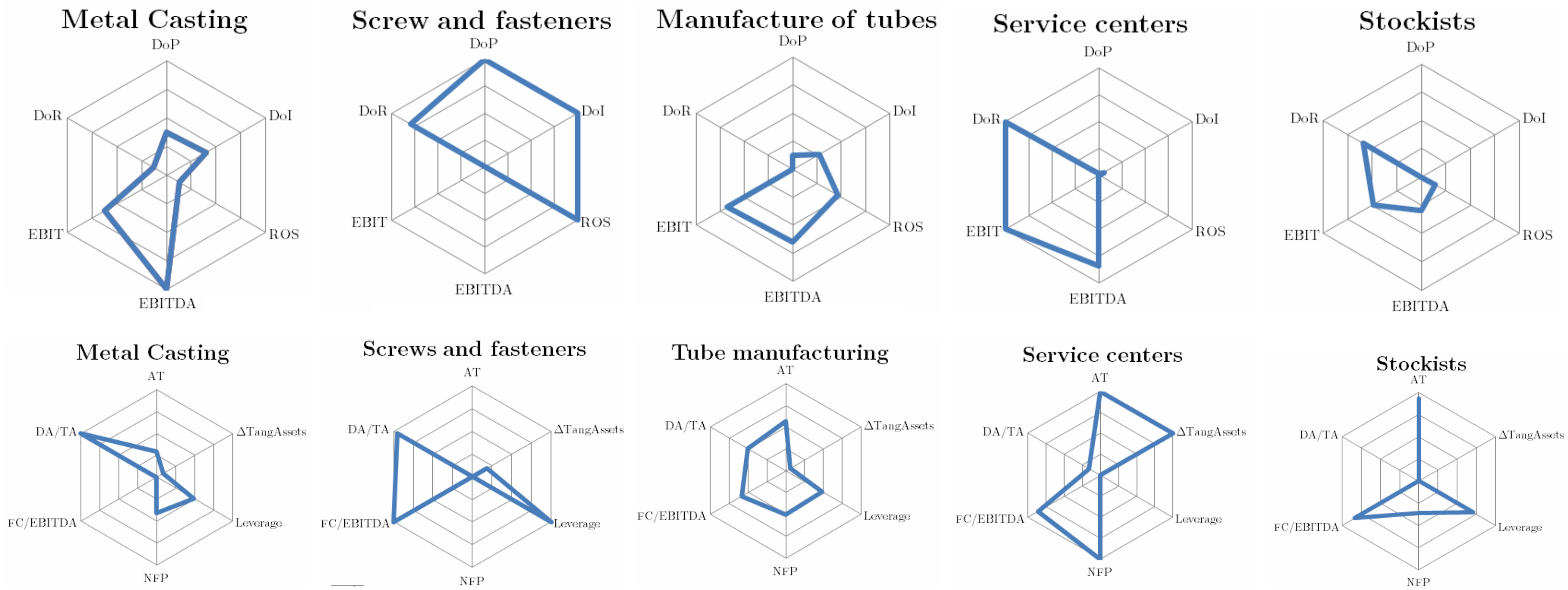


Figure 10: I grafici radar per la supply chain della fabbricazione di tubi.

Valutazione delle soluzioni non canoniche di finanziamento

La stima dello stato di salute di una supply chain presenta un chiaro legame con la valutazione di soluzioni non canoniche di finanziamento, nello specifico, soluzioni di supply chain finance (SCF). Tali soluzioni, sfruttando il legame tra imprese appartenenti alla stessa supply chain, aumentano il valore delle organizzazioni[5] interessate fornendo mezzi di finanziamento alternativi atti all'ottimizzazione del ciclo commerciale e del $WACC$.

Al fine di interpretare i risultati della metodologia di stima dello stato di salute, le soluzioni di SCF possono essere categorizzate in due gruppi: il primo, detto Cash Flow Optimization (CFO), include soluzioni che ottimizzano il ciclo commerciale delle imprese coinvolte; il secondo, detto Alternative Means of Financing (AMF), include le soluzioni che forniscono alle imprese coinvolte mezzi di finanziamento alternativi che sfruttano la forza dei legami tra imprese appartenenti alla stessa supply chain.

Prendendo in considerazione il piano cartesiano riportato in figura 9(c), può essere notato come, considerando i quadranti e non le specifiche coordinate, esistano sedici possibili segmenti (otto segmenti per due, considerando l'orientamento). Questi sedici segmenti possono essere raggruppati in nove cluster. Questi nove cluster presentano caratteristiche che indicano la possibilità che organizzazioni appartenenti ai nodi analizzati possano beneficiare dall'applicazione di soluzioni di SCF alla supply chain, così come la possibilità che tali organizzazioni abbiano un ruolo nel quadro di riferimento di una possibile soluzione di SCF. I nove cluster sono descritti nella tabella 9.

La presenza combinata di nodi appartenenti a diversi cluster influenza le possibilità che una soluzione di SCF posso essere efficacemente applicata alla supply chain. Ad esempio, la presenza di nodi nel cluster 2 (cash provider) e nel cluster 3 (AMF), rappresentano un contesto in cui i secondo possono beneficiare di mezzi di finanziamento alternativi forniti dai primi: specificatamente, è probabile che organizzazioni nel cluster 2 avranno un tasso di interesse sui prestiti uguale ad i_2, mentre quelle nel cluster 3 un tasso i_3, e che i primi possano fornire debito ai secondi ad un tasso $i_k \Leftrightarrow i_2 < i_k < i_3$, benefico per entrambi.

L'interpretazione dei segmenti non può esimersi dalla contestuale interpretazione dei messaggi che provenienti dalle altre parti del modello. Se una soluzione di SCF richiede la presenza di un legame tra due nodi, tale legame dovrebbe essere indagato non solo in termini di di qualità delle relazioni esistenti, ma anche in termini quantitativi: un nodo che fa affidamento quasi interamente sulla produzione estera indebolisce la possibilità di applicare efficacemente una soluzione SCF che riguardi lui e i suoi fornitori. Allo stesso modo, se un nodo presenta caratteristiche adatte ad una soluzione CFO, tale soluzione sarà benefica se includerà i fornitori o i clienti (a seconda delle necessità) più rilevanti in termini di valore scambiato. Tali considerazioni possono essere tratte dalle prime due parti del modello.

Il prototipo

Dopo la definizione del modello, ne è stato sviluppato un suo prototipo computerizzato. Tale prototipo ha l'obiettivo di mostrare le caratteristiche di dinamicità e interattività del modello. Questo permette di sottolineare quelle caratteristiche che difficilmente sono individuabili in un documento scritto, e fornisce intuizioni sull'utilizzo del modello in un contesto pratico.

Il prototipo è raggiungibile all'indirizzo `http://supplychain.altervista.org`. Esso permetta ad un utente, senza approfondite conoscenze dei temi trattati, di stimare lo stato di salute di una supply chain, e di raccogliere informazioni sulla possibile applicazione di soluzioni di SCF riguardo alla supply chain oggetto dell'analisi. L'utente inserisce i dati necessari (n° di nodi, valore degli archi e degli indicatori), e il prototipo produce i risultati desiderati. Il fine del prototipo è di mostrare la possibile integrazione del modello in un pratico strumento: infatti, essendo implementato in uno strumento, il modello può essere usato in modo pratico ed inserito nell'insieme delle analisi richieste per la valutazione dell'applicazione di soluzioni di SCF ad una supply chain, dove può migliorare la qualità delle prime, inevitabili, analisi al livello dell'intera supply chain.

Applicazione e test del modello

Il modello è stato applicato a due supply chain italiane: la fabbricazione di tubi e la fabbricazione di macchinari per l'industria alimentare. L'applicazione ha fornito la base empirica per la fase di test

[5]Definito come: $V(0) = \sum_{t=0}^{\infty} \frac{NCF(t)}{(1+WACC)^t}$

Cluster	Espressione logica[1]	Descrizione
1 High performer	$F \wedge E \wedge P \wedge N$	Il nodo presenta alti valori in ogni parametro.
2 Cash provider	$F \wedge E \wedge P \wedge \neg N$	Il nodo è un *high performer* con una possibilità di investimento (in termini relativi) maggiore delle necessità ($P > N$); organizzazioni in questo nodo sono inclini ad assumere il ruolo di *cash provider*.
3 AMF	$F \wedge E \wedge \neg P \wedge N$	Il nodo presenta un alto valore di N, ed un basso valore di P; è probabile che organizzazioni in questo nodo possano beneficiare di soluzioni AMF, sfruttando legami con altri membri della supply chain che possano fornire debito a condizioni concorrenziali (es.: imprese in cluster 2).
4 Doubtful case	$(F \wedge E \wedge \neg P \wedge \neg N) \vee (\neg F \wedge \neg E \wedge P \wedge N)$	Il cluster racchiude tutti casi di difficile interpretazione in relazione alle soluzioni di SCF. Ulteriori, dettagliate, indagini sono spesso necessarie.
5 Low performer	$\neg E \wedge (\neg F \vee \neg N \vee P) \wedge (F \wedge N \vee \neg P)$	Il nodo presenta una scarsa performance nel generare profitti unita ad una scarsa performance in almeno un altro parametro. È probabile che tale performance non possa essere migliorata attraverso la mera applicazione di una soluzione di SCF.
6 Possible AMF	$\neg E \wedge F \wedge \neg P \wedge N$	Questo nodo presenta caratteristiche simili ai nodi in cluster 3, ma la sua bassa performance in generazione dei profitti indebolisce l'opportunità che soluzioni AMF siano applicabili.
7 CFO	$E \wedge \neg F \wedge (P \vee \neg N)$	Il nodo presenta una forte performance in generazione dei profitti, ma una debole performance nella gestione dei flussi di cassa: è quindi idoneo all'applicazione di soluzioni di cash flow optimization.
8 SCF needy	$E \wedge \neg F \wedge \neg P \wedge N$	Il nodo presenta caratteristiche comuni ai cluster 3 e 7, rendendolo idoneo all'applicazione di entrambe le soluzioni di SCF.
9 Potential cash provider	$\neg E \wedge P \wedge \neg N$	Con caratteristiche simili al cluster 2, la possibilità che organizzazioni in questo cluster possano assumere il ruolo di cash provider è negativamente influenzata dalla bassa performance in generazione di profitti.

[1] Un parametro è detto vero se > 0, falso altrimenti. Convenzione: AND $\rightarrow \wedge$, OR $\rightarrow \vee$, NOT $\rightarrow \neg$.

Table 9: I nove cluster identificati.

e sviluppo del modello. Il test è stato basato sul confronto dei messaggi derivanti dall'analisi delle fonti secondarie (comprese le interviste), e da quelli provenienti dall'applicazione del modello. Molti dei messaggi identificati dall'applicazione del modello hanno trovato un parallelo nell'analisi delle fonti secondarie, e vice versa. In particolare, si sottolinea:

- I centri servizio (che fanno parte del comparto distributivo della fabbricazione di tubi) cadono nel cluster 7 (Cash Flow Optimization), data la loro alta performance nella generazione di profitto, e bassa nella gestione dei flussi di cassa. Questo è confermato dall'analisi delle fonti secondarie, che sottolineano il rapporto difficoltoso dei centri servizio con i fornitori, che possiedono un maggior potere di contrattazione;

- I distributori dal pronto (che appartengono allo stesso comparto dei centri servizio) presentano una performance debole (cluster 5), confermata dall'analisi delle fonti secondarie. Tale nodo soffre la stessa criticità dei centri servizio, ma senza la possibilità di adattare i prodotti alle specifiche esigenze dei singoli clienti (come i centri servizio), fattore che è probabilmente alla causa della cattiva performance in generazione dei profitti.

- I coefficienti di produzione per la fabbricazione di macchinari per l'industria alimentare sottolinea come questi non facciano particolare affidamento su uno specifico nodo di fornitori, come segnalato dall'analisi delle fonti secondarie.

Conclusioni e sviluppi futuri

Il modello sviluppato in questo lavoro è focalizzato sulla necessità di sviluppare una metodologia per la stima dello stato di salute di una supply chain, basata su una rappresentazione standardizzata della supply chain, che fornisce una rappresentazione della struttura della supply chain attraverso strumenti grafici e tabulari, sottolineando forza e dipendenza nei legami tra i nodi. La metodologia effettua tale stima per ogni singolo nodo, in relazione all'intera supply chain. Il risultato fornisce messaggi riguardanti l'applicazione di soluzioni di SCF all'intera supply chain. In particolare, gli output del modello possono essere usati per stimare la possibilità che organizzazioni all'interno di uno specifico avranno benefici dall'applicazione di soluzioni di SCF, così come quella che organizzazioni siano adatte a rivestire specifici ruoli nel quadro di riferimento di una soluzione di SCF.

Un prototipo basato sul modello è stato sviluppato[6] con l'obiettivo di sottolineare l'utilizzo pratico del modello all'interno delle necessarie analisi per l'implementazione di soluzioni di SCF ad una supply chain. Tale uso presenta diverse implicazioni manageriali: una corretto utilizzo del prototipo (o di eventuali evoluzioni) può essere utile ad istituzioni finanziarie, associazioni di filiera, e semplici organizzazioni, specialmente se interessate alla valutazione di soluzioni di SCF; infatti, un organizzazione che voglia analizzare i benefici di una soluzione di SCF, spesso non può evitare una prima analisi al livello dell'intera supply chain, che può essere facilitata dal corretto utilizzo del presente modello. Sviluppi futuri includono:

- Modifiche della struttura del modello e ulteriori validazioni, incluse successive applicazioni del modello per ulteriori test: si dovranno testare differenti insiemi di misure rispetto a quello proposto, anche di natura non finanziaria, così come il modello dovrà essere applicato a supply chain di natura non manifatturiera;
- Modifiche relative al supply chain finance, incluse la considerazione di ulteriori soluzioni (meno conosciute o non ancora sviluppate). Inoltre, è possibile modificare il modello per includere una analisi quantitativa dei benefici della specifica applicazione di soluzioni di SCF alla supply chain;
- Indagini relative al legame tra una corretta implementazione di pratiche di ICT (come ad esempio un sistema di fatturazione elettronica) nella supply chain e i risultati della metodologia di stima dello stato di salute, così come un'analisi dell'impatto di tali pratiche su possibili soluzioni di SCF;
- Il prototipo può essere migliorato; in particolare, un intero software può essere sviluppato per l'effettivo utilizzo nelle analisi di valutazione dell'applicazione di soluzioni di SCF.

Sigla	Nome per esteso
G1	Motori
G2	Rubinetti e valvole
G3	Ingranaggi
G4	Lavori di meccanica generale
G5	Telai e parti di telai
G6	Macchinari per l'industria alimentare
G7	Fusione di metallo
G8	Viti e bulloni
G9	Fabbricazione di tubi
G10	Centri servizio (tubi)
G11	Distributori dal pronto (tubi)

Table 10: Legenda per le tabelle e figure di questo sommario.

[6] Disponibile all'indirizzo `http://supplychain.altervista.org`.

Chapter 1

Literature Review

This first chapter highlights the more relevant contributions coming from the literature analysis carried out as theoretical basis of this work. Such review is divided into two parts: the first one includes the illustration of the most common definitions of supply chain, followed by the analysis of the topics of Supply Chain Management and Supply Chain Finance; thus, it presents recent models, tools, and prototypes developed for the representation of a supply chain, to conclude with the analyses of relevant models and methodologies for the financial assessment of a supply chain. The second part concerns the literature framework for the context analysis on which the application of the model (cf.: chapter 4) is based.

1.1 Supply Chain Definition

The supply chain is a concept that, over the past 30 years, gained great attention in academic literature. It has been defined in many ways, in the last years usually in connection with the definition of Supply Chain Management. Among the most used definition of Supply Chain, Mentzer et al. [2001] define it as:

> A set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flow of products, services, finance, and/or information from a source to a customer.

Lambert et al. [1998] define it as:

> The alignment of firms that brings products or services to markets.

And La Londe and Masters [1994] define it as:

> The integrated movement of materials throughout the firms in a organic and systemic way.

These definitions include only a specific segment of the product flow that goes from the initial source of materials to the final consumption. On the other end, Stevens [1989] defines it as:

> The interconnected series of activities concerned with the planning and controlling of raw materials, components and finished products from suppliers to the final consumer,

including therefore all the players (directly) involved in a production process, included the final customer. A third alternative is the definition provided by the Supply Chain Council (Supply Chain Council [2012]):

> The supply chain encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer.

It focuses on a specific firm, and than define the SC from it selecting the segment of the product flow that goes from its supplier's supplier to its customers' customer.

All these definitions can be analyzed regard to the two dimensions that define the scope of a supply chain (Cooper et al. [1997]): number of tiers involved, and activities\functions involved. The former represents the length of the segment of production considered (express in number of tiers): a focal company (tier 0), its direct suppliers and customers (tier 1), its suppliers' suppliers and customer's customers (tier 2), and so on up or down the chain to the first sources or to the points of consumption (n-th tiers); the latter dimension represents instead the activity, and therefore the typology of firms involved: from the only commercial or industrial firms (the ones who transform and/or sell the product), to companies not directly involved in this type of activities: Logistic Service Provides (LSP), financial institution and all the enterprise that have a relationship with the focal company. Mentzer et al. [2001] state that, regarding these two dimensions, three supply chains can be defined: the "direct" (fig. 1.1(a)), the "extended" (fig. 1.1(b)), and the "ultimate" (fig. 1.1(c)) supply chain. However, as highlighted at the beginning of the section, literature developed definitions that satisfy other combinations.

The literature contributions presented so far, however, take into consideration supply chains only focused on focal company: the Mentzer definition, for example, includes in the supply chain a number of different typologies of companies, but its definition of extended supply chain does stay within the concept for which a company's supply chain is inherently different from another company's one: the supply chain is "something" that change company by company, it is firm-specific, and firm-centric. The definitions presented above represent a supply chain built around a *focal company*; two companies, A and B, that produce the same product, using the same raw materials and offering it to the same final market have two different supply chains[1]; even inside a supply chain, if the focal company changes, the supply chain may change. A step in the development of a different typology of supply chain definition is the concept of "multi-owned supply chain", defined as a supply chain in which persists a fair balance of power among more autonomous enterprises that join in (Terzi and Cavalieri [2004], Lyons et al. [2012]); however, this concept is still based on a view of the supply chain "personalized" from company to company: even if autonomous company join a logistic network, the supply chain represented would be the supply chain specific of that logistic network, even add or removing a company would mean create a new supply chain.

[1] Except of course if they have exactly the same suppliers, exactly the same customers, and so on, but this is unlikely.

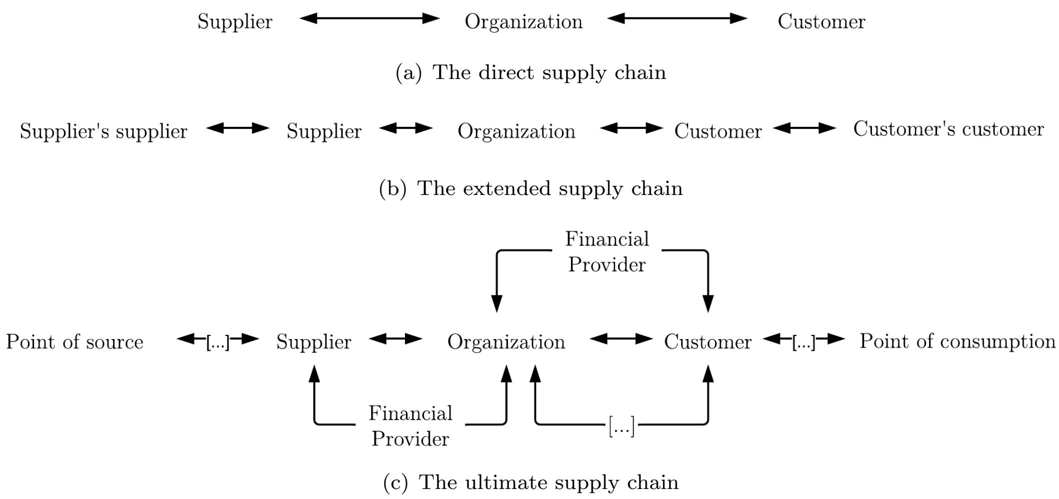


Figure 1.1: The three supply chains defined by Mentzer et al. [2001].

Even if it is not directly addressed, a different concept of supply chain does exists; for example, more than a master thesis from Politecnico di Milano (e.g: Carcano and Ghiggeri [2005], Haristos and Guglielmetti [2005], Casartelli and Somaini [2004]) represents a supply chain that do not exactly fit any of the definitions provided above: it is not focused on a single organization, but represents groups of organizations that share the production of the same product(s), need the same raw materials, and serve the same final markets; each company could source from different suppliers that provide the same raw materials, but this is not clasped by this type of representation. It is more related to a "statistical" representation of product families flows through different state of production, than to the punctual representation of company-specific processes among organizations. An example of this type of representation is reported in figure 1.2.

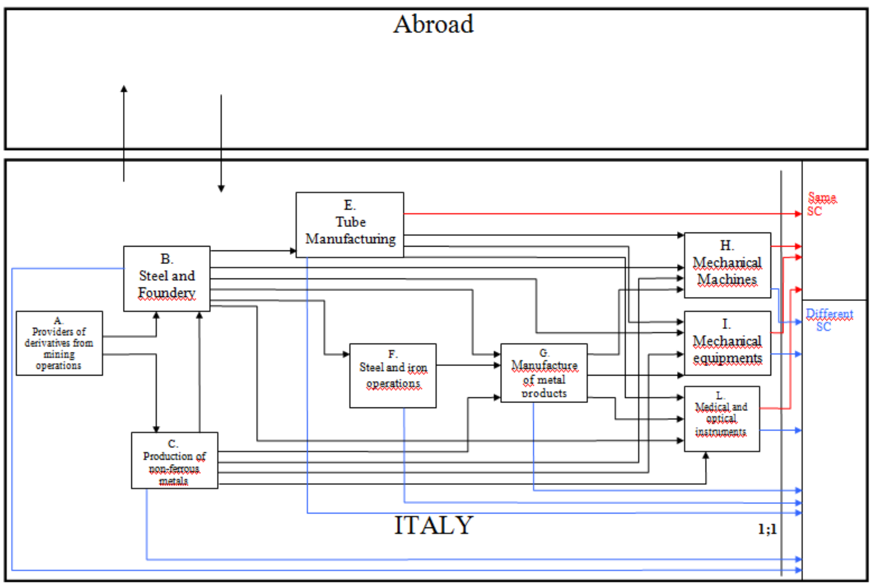


Figure 1.2: A representation of the mechanical supply chain.

Source: Casartelli and Somaini [2004], translation from Italian by the author.

However, this "typology" of supply chain is neither well-defined, nor standardized in its representation, nor its differences from the known definitions have been stated out.

1.2 Supply Chain Management

As stated above, the *supply chain* is a concept that has seen a sharp increase in attention from literature together with the concept of *supply chain management* (SCM), around the late '80s. However, besides this more than 30 years of research, an unique definition of SCM is still matter of discussion. A steam of literature affirms there are two different concepts called both ambiguously Supply Chain Management (Mentzer et al. [2001]):

- Supply Chain Orientation: the idea of viewing the coordination of a supply chain from an overall system perspective, with each of the tactical activities of distribution flows seen within a broader strategic context.
- Supply Chain Management: the actual implementation of this orientation across various companies in the supply chain.

Should be noticed that this repartition implies the existence of a Supply Chan whether it is managed or not. A definition of Supply Chain Management is provided by the Council of Supply Chain Management Professionals (CSCMP):

> Supply chain management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance, and information technology.

In general terms, SCM is part of a framework composed by four interconnected components:

- Supply Chain Management;
- Business Processes: all the activities that produce a specific output of value to the customers;
- Management Components: what structures and manages the business processes;
- Supply Chain Structure: the configuration of companies within the supply chain.

All these components are interconnected among each others, and connected with the SCM, as summarized in figure 1.3.

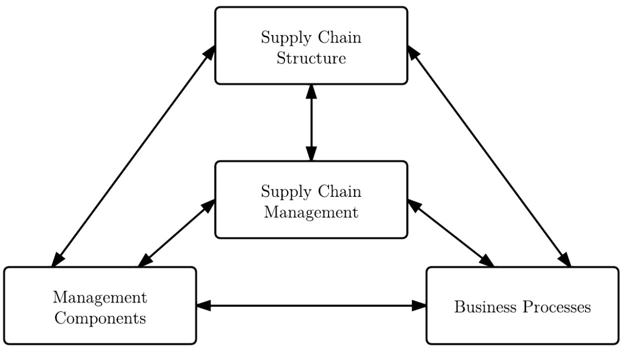


Figure 1.3: SCM Framework

Source: Cooper et al. [1997]

SCM is known to bring substantial benefits if effectively implemented, of which the most important are (Mainardi et al. [1999], Gryna [2001], Jacobs [2004], Mentzer et al. [2001]):

- Savings on inventories carrying and other logistics costs;
- Improved quality of the services provided, such as the ability to meet customer requests;

- Increased company productivity and profitability, included employees productivity;
- Reduced risks;
- Improved cash flow cycle time;
- Reduce purchasing price.

Anyway SCM has developed, initially, in replay to the increasing needs of reliability, competition on time and quality, faster deliveries, punctuality, and so on; the competition among companies and suppliers (and customers) was no long an option, the links in the supply chain needed to be exploited in a systemic and collaborative view (Calantone et al. [1999], Gryna [2001], Mentzer et al. [2001]).

But later on SCM increased in importance also as tool for cope with demand and supply uncertainty: the concept of *agile supply chain* (Lee [2002]) is one of the numerous examples of models that manage the supply chain to adapt and cope with the environment. But together with the increase in opportunities and benefits of applying SCM, also the activities needed to an effective application increased; Mentzer et al. [2001] state that a certain number of SCM activities that a company shall implement to adopt an effective SCM philosophy:

- Integrated Behaviour;
- Mutually Sharing Information;
- Mutually Sharing Risks and Rewards;
- Cooperation;
- The Same Goal and the Same Focus on Serving Customers;
- Integration of Processes;
- Partners to Build and Maintain Long-Term Relationships.

1.2.1 Barriers to Supply Chain Management implementation

The main barriers to an effective SCM implementation can be divided into two groups (Park and Ungson [2001]):

- Inter-firm rivalry: a misalignment of motives and behaviors among allying partners within the strategic supply chain, the tendency to compete rather than willingly cooperating; under this category we can find lack of trust, turf protection, poor collaboration among partners, and so on.
- Managerial complexity: a misalignments in allying firms' processes, structures, and culture; under the umbrella we can find information system and technological incompatibility, inadequate measurement systems, and conflicting organizational structures and culture: basically, firms are more comfortable using their systems for their own tasks, and people are not willing to share information fearing to expose their company's weaknesses (Sheridan and Leibs [1999], Gopal et al. [1998], Fawcett et al. [2008]).

Summarizing, nowadays-SCM is not driven anymore by the only cost reduction, but customer satisfaction and service is becoming an equally powerful motivator for the implementation of collaboration practices in supply chains. On the other side, technologies advancements decreased the problems related to platforms misalignment, but not the "people issues": culture, trust, aversion to change, willingness to collaborate are barriers to SCM implementation that need resource and efforts to be bridged; people are the key to successful SC collaboration (Fawcett et al. [2008]).

1.2.2 Trends in Supply Chain Management

The Sustainable Supply Chain Management

From its introduction, the concept and the practices of SCM changed completely, extended its boundaries as well as its philosophy. These changes have not came to an end: nowadays new concepts arise around SCM, brining new understanding about what SCM is, and shaping its innovative practices. One of these new stream is the so-called "sustainable supply chain management" (SSCM). Sustainable Supply Chain Management is defined as (Seuring and Müller [2008]):

> the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking into account goals from all three dimensions of sustainable development (economic, environmental and social), which are derived from customer and stakeholder requirements.

The framework at the base of SSCM is represented in figure 1.4). As can be seen, SSCM encompasses the practices that are "sustainable", i.e., that are characterized by a good economical, social, and environmental performance. Practices that provide these three characteristics are "SSCM practices"; some example of them can be:

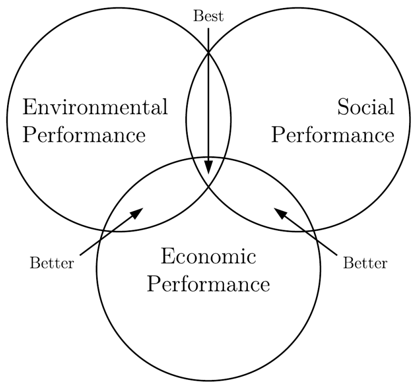


Figure 1.4: A general framework for SSCM.

Adapted from Seuring and Müller [2008].

- The reduction of waste and the optimization of the product packaging as a clear environmental advantage, may increase the position of the company in front of the society, and lead to cost reductions in the packaging material and process (Mollenkopf et al. [2005]);
- Proactive participation in economical and social regulation shaping may have an economical return in terms of comparative advantages, especially if those regulations are modeled over the company's own existing products (Carter and Dresner [2001]);
- Improving health and safety condition in the plants is easily translatable in costs saving for the management of incident to people or to the environment (Seuring and Müller [2008]).

In general terms, literature showed in the years that a company that engages in social and environmental positive behaviors is more attractive for suppliers, customers, employees, and shareholders (Capaldi [2005], Ellen et al. [2006], Klassen and McLaughlin [1996]). It may seem trivial, a way to earn points as good corporate citizens, but it is not just so. A sustainable supply chain management is a new development of the old concept at the base of SCM: collaboration; collaboration goes nowadays beyond the simple share of information, extending to the increase of the social and environmental performances: it is known that produce in a socially responsible manner enhances a company performance (Ganesan et al. [2009]).

The e-Supply Chain Management

An other noteworthy trend in SCM is the so-called e-Supply Chain Management (e-SCM), that can be defined as:

> The impact that Internet has on the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders (Giménez and Lourenço [2004]).

In practical terms, e-SCM merges the Internet and SCM in order to enhance decision making by providing real-time information and improving collaboration among partners. Among the different classification of e-SCM practices and activities we provide the one suggested by Norris and West [2002], and well summarized by Al-zu'bi [2010], that identify six categories of e-SCM practices:

- **e-Planning**, e.g.: collaborative forecasts, collaborative supply plan to support demand, all based on the Internet;
- **e-Replenishment**, e.g.: integrated production and distribution process;
- **e-Procurement**, e.g.: web-based technology to support requisitioning, sourcing, contracting, ordering and payment;
- **e-Collaboration**, e.g.: product design and development techniques to optimize the time to market;
- **e-Logistics**, e.g.: web-based solutions for the optimization of the warehouse processes, the inventory tracking, and the route problem;
- **e-B2B exchange**, a general Business to Business (B2B) exchange based on the web.

As regards the e-SCM benefits, they are mostly related to the increased easiness of communication and information sharing among partners, but this should not be misinterpreted: it is not the e-SCM solution *per se*, but the willing of the partners to increase the amount of information shared that creates the benefits (Lancaster et al. [2006]). Such benefits in practical terms can be the decrease of the so-called bullwhip effect[2] (Grossman [2004]), with the consequently decrease in inventory carrying costs and inefficiencies in production; of course the use of the Internet upon a part or the whole Order to Cash (O2C) cycle brings other costs reduction, among which the ones related to dematerialization (Perego and Catti [2011]). A benefit that should not be overlooked is the function ofthat e-SCM holds of long-term partnership enabler: e-SCM allows companies to focus on their own core competencies, refocusing strategy and stabilizing processes; the level and the nature of the information shared increase the possibility for a long-term partnership among partners (Tapscott [2001]).

Of course e-SCM has drawbacks as well, most of which related to the commitment of the firms involved, and to a fair sharing of the benefits: no company can implement a solution among partners if are the only one that will benefit from them (Lancaster et al. [2006]). A second stream of drawbacks is related to the true freedom of information: a known issues in the application of e-SCM solutions is that companies are not willing, for lack of trust among each others, to exchange the crucial information needed to "bring" home the benefits of the program (Scalet [2001]). Another drawback is the other side of the coin respect to the long-term partnership: long-term partnerships may make a firm products easily copied, translating competition in the supply chain from differentiation to price (Lancaster et al. [2006]).

1.3 Supply Chain Representation

Supply Chain Representation (SCR) is a concept that gained attention in literature with the increased popularity of SCM-related topic in the last years; in particular, the concept of SCR used in this thesis (that sometime overlaps with the concept of Supply Chain Simulation, and Supply Chain Modeling) can be traced back to the '90s, where improvements in computer simulation, software potentialities, and

[2]The bullwhip effect is defined as the phenomenon that occurs when the demand order variabilities in the supply chain are amplified as they moved up the supply chain. (Lee et al. [1997])

computerized control systems, allowed SCM practices to expand in new areas, expanding simultaneously the possibilities and needs for an effective representation of the supply chain. The topics encompassed within the SCR framework are numerous, and can be classified respect to a great number of variables, e.g.: purpose (simulation, modeling, control, etc.), level of formalism, semantic, ontology, or more specifically variables taken into account, or behaviors that can be represented. To classify the relevant literature, two approaches are proposed: a quantitative one, aimed at provide a more complete picture of the current literature, and a qualitative one, aimed at analyzing in detail the most relevant contributions.

1.3.1 A quantitative approach to SCR literature contributions

As regard the quantitative classification, table 1.3 summarizes the findings; the methodology followed divided the papers regards to the variables presented in table 1.2; some of the variables taken into account are proposed by literature itself, as in the case of Labarthe et al. [2007], that propose a classification of supply chain representation model in three categories, summarized in table 1.1:

Name	Description	Advantages	Disadvantages
Organizational	Based on system theory and process mapping	Power of explanation, low complexity	No time dimension
Analytical	Models processes through mathematical formulation of the SC	Formality, precision	Strong hypotheses, limited consideration of time
Simulation	Uses continuous/discrete simulation to map the SC, divided in equation-based[1] and agent theory	Fully account of time dimension	Lack of common language, ontology, semantics, etc. (cfr.: Drogoul et al. [2003])

[1] the equation-based can be divided into: spreadsheet simulation, system dynamics, discrete event simulation, and business games (Kleijnen [2005], Powell [1997]).

Table 1.1: Classification of supply chain representation models.

Source: adapted from Labarthe et al. [2007].

Variable	Description	Admissible values
SCL	Maximum supply chain level (in no. of tiers) representable	n: n tiers C: customisable
BoM	Explicit consideration of bill of material	x: yes
Dis	Explicit consideration of retailing/distributor tier	x: yes
Gra	Formulation as a mathematical graph[1]	x: yes
Geo	Consideration of geographic distribution of the SC	x: yes
ToS	Type of SC modeling (cf.: Labarthe et al. [2007])	O: organizational A: analytical SE: equation-based simulation SA: agent-theory simulation
Lan	(Meta)language used for developing the eventual tool	Name of the language
DS	Development stage	C: conceptual S: At least prototype developed E: Experience with a softwares
Obj	Objective of the model, software, or tool described	DS: Decision support system ND: Network Design problem NL: Node Localization problem
GP	Scope is wider than representing/modeling a SC[2]	x: yes

[1] When Gra=x, the supply chain is represented as a graph $\mathcal{G} = (V, E)$ of V nodes and E arcs.
[2] Only for commercial software.

Table 1.2: Variables used for classify SCR literature contributions.

Contribution[1]	LS	BoM	Dis	Gra	Geo	ToS	Lan	Obj	DS	
Antosz [2005]	C		x			O	n.d.	DS	E	
Barroso et al. [2011]	1	x				O		DS	C	
Biswas and Narahari [2004]	1		x		x	SE	Java	NL+DS	S	
Chatfield et al. [2009]	C		x		x	O	XML	DS	S	
Chatfield et al. [2007]	C		x		x	O/SA	XML	DS	S	
Damodaran and Margo [2011]	C		x		x	O	n.d.	DS	E	
Ding et al. [2004]	C		x		x	O/A		DS	S	
Dogan et al. [2004]	C			x		A	n.d.	DS	E	
Fayez et al. [2005]	2	x			x	O	XML	DS	S	
Huang et al. [2005b,a]	C	x		x		A		ND	C	
Labarthe et al. [2007]	C		x			SA	Java	DS	S	
Liu et al. [2004]	C		x			O	SIMAN/ARENA	DS	S	
Nagurney and Toyasaki [2003]	1		x	x		A		DS	C	
Robbins Bush [2002]	C		x		x	O	n.d.	DS	E	
Rossetti and Chan [2003]	C		x		x	O	Java	DS	S	
SCOR [2008]	2					O		DS	S	
Yablonski et al. [2003]	C		x		x	O	n.d.	DS	E	
Commercial Software										GP
Almeder and Preusser [2007]	C		x		x	SA/SE	AnyLogic[2]	ND+NL+DS	E	x
Kelton et al. [2010]	C		x		x	SE	ARENA[1]	ND+NL+DS	E	x
ARIS - User manual [2012]	C					O		DS	E	
Ebrahimy et al. [2011]	C		x		x	SE		ND+NL+DS	E	x
Supply Chain Guru [2012] Manuj et al. [2009]	C		x		x	SE		DS	E	
TIBCO Business studio - User guide [2012]	C					O		DS	E	x

[1] The temporal limit for contribution has been set at year 2002 (10 years ago).
[2] Proprietary Language

Table 1.3: Classification of literature contribution on SCR with relevance respect to this work.

Two other classification variables are proposed by Terzi and Cavalieri [2004]: the objective and the development stage of the representation model; the former represents the purpose of the model, tool, or software analyzed, divided into: decision support, supply chain network design, and supply chain node localization[3]; the latter represents the development state of the tool, model, or software analyzed, divided in: conceptual, already developed (included prototypes), and software experience paper.

Contributions summarized in table 1.3 comes from a great number of fields: e.g.: "Supply Chain Simulation", "Supply Chain Modeling", "Supply Chain Profiling", and so on; comprehensibly, those topics are much more larger than the one addressed in this work, therefore the contributions listed, as represented in figure 1.5, represent only a part of the topic to which they belong, the part the overlaps with the concept of SCR used in this work.

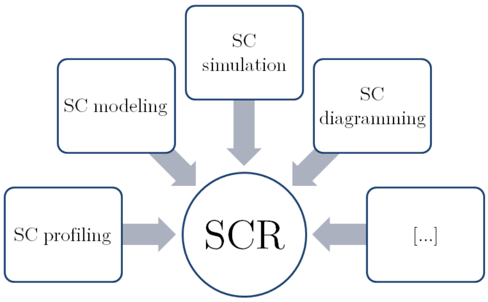


Figure 1.5: Main areas providing contributes to the SCR literature.

Source: elaboration of the author.

As can be understood from the summarizing table 1.3, the contribution that present relevant contents respect to this work are for the great part located in the decision-support area; a less numerous majority of contributions fall into the Operational typology of SC modeling (cfr.: fig. 1.6). Almost all the contribution explicit consider the distribution tier in the supply chain representation, and almost all made the maximum supply chain level considerable customisable: only a few considered only one tier, and someone (usually SCOR based model) used two tiers. Few paper used a mathematical graph approach.

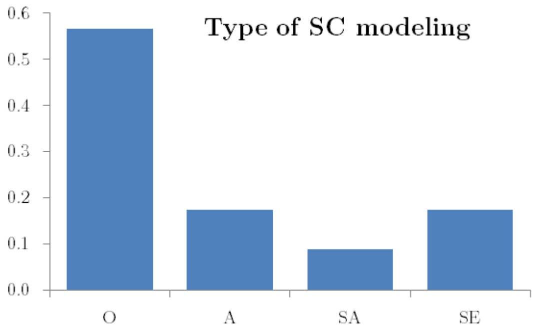


Figure 1.6: Literature considered by SC modeling typology (% on total).

Source: elaboration of the author.

1.3.2 A qualitative analysis of most relevant contributions

After this picture of the literature review of SCR, our analysis can focus on the main stream of research that, with the only purpose of readability, we can call Chatfield, Cope-Fayez, and software stream.

[3]Model that address the supply chain design and node localization solve the problem of, respectively, design the optimal network (no. of echelon, type of warehouses, and so on) and geographically localizing nodes within the supply chain

Chatfield stream

The "Chatfield stream"[4] revolves around the work of Chatfield, Harrison, and Hayya, from the university of central California. It regards the development and applications of the *SCML* (Supply Chain Modeling Language), an XML-based language for supply chain mapping and representation, the *VSCE* (Visual Supply Chain Editor, presented in figure 1.7), a Windows based editor to represent supply chains created through the SCML, and the *SISCO* (Simulator for Integrated Supply Chain Operations), a Java-based tool that simplifies the definition of the supply chain.

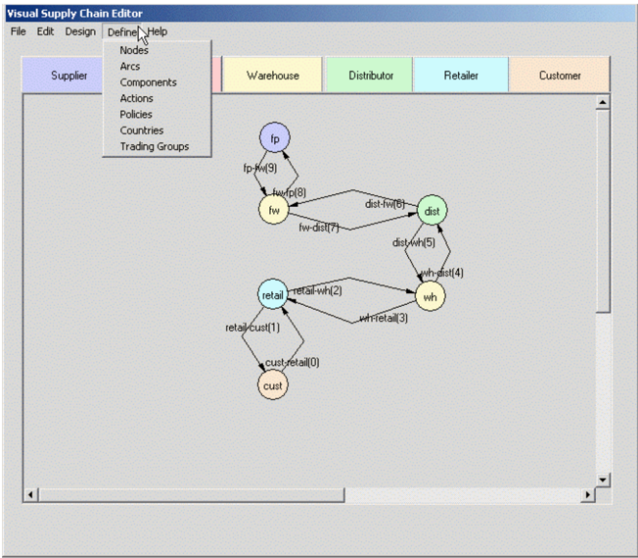


Figure 1.7: Chatfield's Visual Supply Chain Editor.

Source: Chatfield et al. [2009].

The unit of analysis of this tool is the single supply chain.

The implicit definition of supply chain on which is based this model is similar to the one of Stevens [1989]; there is in fact a focal company, with its specific suppliers and customers, and it is possible to map as many tiers as one wishes. Straightforwardly the ontology (presented in the next section), includes entities such as policies and action: it is meaningful to define and map those characteristics if the unit of analysis is the single company.

The purpose of this tool is to simulate scenarios composed by different combinations of the definable objects, to understand which of the scenarios minimize defined performance measures. In practical terms, a typical use may be to monitor a cost function with different policies in terms of stock management or reorder points to understand which combination is less costly.

Even if the formal description of the model does not take into consideration the supply chain as a mathematical formulation of a graph, the structure that constitute the output of the tool does present the supply chain in a graph-style. Nevertheless, it is possible to introduce the geographic dimension.

The tool requires the user to firstly define a static structure of the supply chain, then define the parameters needed to run a simulation (stopping rules, replications, and so on), to finally launch such model simulation and analyze the report generated.

The ontology The ontology developed within the Chatfield stream is based on few components, some of which quite flexible in their use. The basic components are:

- **Node:** represents any physical location within the supply chain. It is characterized by a name, a type (warehouse, distribution center, plant, ...), and a display attribute (to locate it in a map), and other relevant characteristics;

[4]Namely: Chatfield et al. [2001a,b, 2003, 2006, 2007, 2009]

- **Arc:** represents a connection between two nodes. It is characterized by the typology of arc (railroad, roadways, or electronic connections), the physical location of the arc, the amount and typology of object transported and the container unit (that define the unit of transportation of the arc);
- **Component:** represents any object that can be input, output, moved within, or used by a supply chain, for example money, information, raw materials, components, and so on;
- **Action:** represents a transformation that occur within the supply chain, e.g.: production processes, order placement, forecasting, transporting, receiving, and so on;
- **Policy:** represents any managerial policy or logic rule that govern the supply chain, such as inventory and replenishment policies, or routing rule;

The ontology has been developed via XML language.

Cope-Fayez stream

The "Cope-Fayez stream"[5] revolves around the work of Cope, Fayez, Mollaghasemi, and others, from the university of central Florida, and from the company *Productivity Apex, Inc.*, located in Florida as well. The work regards an, as yet unnamed, XML- and Java-based tool for the definition and the representation of supply chains.

The unit of analysis of this model is again the single supply chain, with its specific suppliers and customers. In particular, the high levels of the tool are shaped on the SCOR model (from which it inherits the definition of supply chain), that formally limits to two the number of tiers of suppliers and customers.

The initial model and its successive modification followed all a specific methodology, reported in figure 1.8.

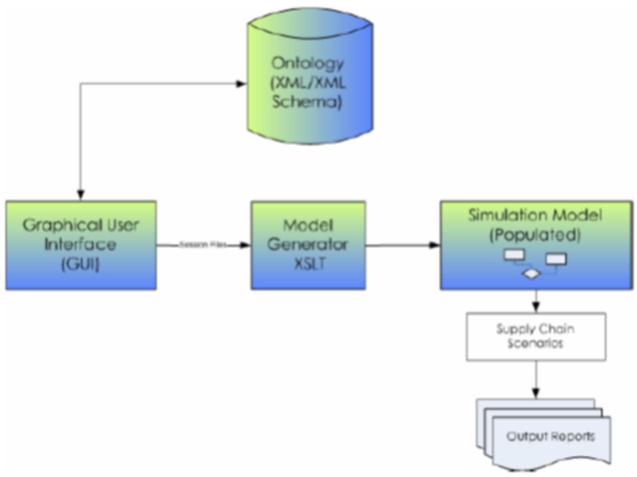


Figure 1.8: Cope and Fayez's tool methodology.

Source: Cope [2008].

The model developed expects the user to complete four steps:

1. Define the supply chain populating a database based on the model ontology;
2. Define supply chain operational scenarios, that is, provide meaningful combinations of the database entry inserted;

[5]Namely: Fayez et al. [2005], Fayez [2005], Fayez et al. [2006], Cope et al. [2007], Cope [2008]

3. Run the simulation experiments for the scenarios;

4. Generate output reports that illustrate the simulation results in terms of the Performance Measures previously defined.

The ontology The ontology developed by Fayez and Cope presents some difference from the Chatfield's one. The basic elements of the ontology in question are:

- **Functional units:** represents any facility of the focal company, supplier, supplier's supplier, customer, carriers, and so on;
- **Products:** defines any physical material that will move through the system, including final products, raw materials, and components;
- **Bill Of Materials:** defines the structure of the products in terms of (sub)components;
- **Functional Unit and Product Relationships:** represents any transformation of sourced products into finished and delivered one, performed by a functional unit;
- **Sourcing Policy:** defines policies used to source the products, such as suppliers' lead time and determination;
- **Inventory Policy:** defines the policies used to manage stocks of products, including replenishment policies, reorder points, order quantities, and so on;
- **Production Policy:** defines the policies used to produce the products, such as the *make* policy and the production lead times;
- **Delivery Policy:** defines the policies used to deliver the products to the customers, including destination specifications, transportation modes, and so on;
- **Return Policy:** defines the policies used to return the products, similarly to the delivery policy, considering also the type of return;
- **Resources:** represents any available resource at each functional unit;
- **Objects:** represents any object that does not fall into the product category flowing in the supply chain;
- **Performance Measures:** represents any measure that will be used to assess the supply chain performance; only SCOR measures (from any level) are allowed.

The ontology has been developed using the Web Ontology Language (OWL[6]).

Software stream

The software stream, as far as it concerns the purpose of this thesis, can be divided into two parts: the Simulation-based[7], and the the BMP-based (Business Process Management)[8]; should be noticed that field of simulation software is very wide, and, from a technical point of view, there are a great number of simulation software that could map (and simulate the behavior of) a supply chain; however, this section aims at mapping the only software that explicitly takes into consideration the supply chain simulation, and in particular, that software that fits in with respect to the concept of supply chain representation presented later on in this work.

[6] If the reader wonders why the acronym of Web Ontology Language is OWL and not WOL, it is a tribute to William Martin's *One World Language* project of the mid '70s

[7] Among all the contributions: Almeder and Preusser [2007], Kelton et al. [2010], Manuj et al. [2009], Ebrahimy et al. [2011], Supply Chain Guru [2012].

[8] Among all the contributions: TIBCO Business studio - User guide [2012], ARIS - User manual [2012].

Simulation stream The software that approach the representation of the supply chain from the simulation point of view (of which an exmple is reported in figure 1.9) usually provide an environment in which is possible to put objects that represent physical points of interest, assign to this object behaviors (through equations, agent theories methodologies, and so on), and links to other objects; in this way is possible to link known variables (inputs) to unknown variables of interests (outputs). The relevant point is that this software are clearly divided into two phases: the *preparation*, and the *execution* (usually accomplished clicking a "play" button): in the execution phase the links, behaviors and other characteristics of the system created in the preparation phase are tested through reiterated interactions in a simulated time, to understand the effect that the input variables have on the output variables.

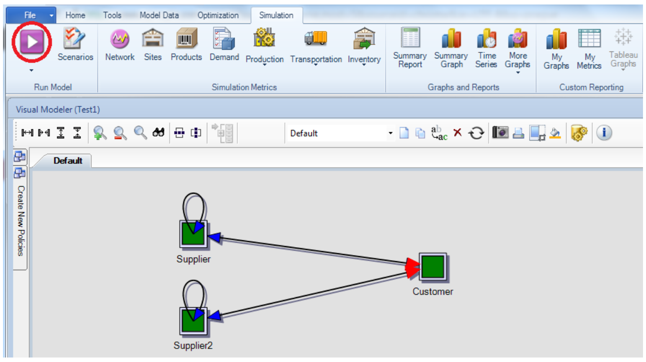


Figure 1.9: Supply Chain Guru screenshot.

Circled: the typical play button of simulation software.

BPM stream The software that approach the representation of the supply chain from the BPM point of view provide as well an environment in which is possible to put objects, but usually those objects do not represent physical objects, but tasks carried out by parties (manually or automatically). The purpose of mapping a supply chain through a BPM software is to *map* the processes that occur within the supply chain, using the objects, semantics, and rules provided by the BPM; the classical example of representation of a supply chain through one of those software is the representation of the order-to-cash cycle, that can span through an indefinite number of tiers. Comprehensibly, the representation of supply chains through BPM software is usually relegated to a minimum number of tiers, and is enterprise-centric. An example of representation of supply chain through BPM is reported in figure 1.10.

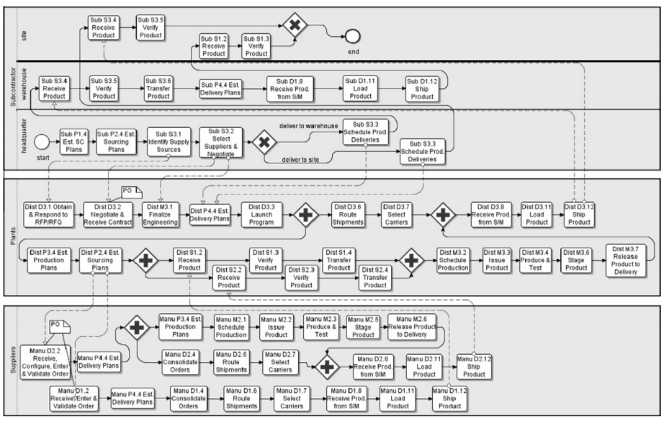


Figure 1.10: A representation of a supply chain through BPMN based on the SCOR methodology.

Source: Cheng et al. [2010].

The main differences between the two typology of software are that in the BPM stream the graphical representation is focused on the processes, and not on the players or on the physical locations, that are often secondary in the graphical scheme, if not hidden. On the contrary in the simulation stream the focus of the graphical representation are the player and the geographical locations, while the processes are presented in form of players behaviors conditioned by standardized rule and policies, and are always absent from the graphical scheme.

1.4 Supply Chain Finance

Historically, players in the supply chain have always seek the maximization of their own profit, being they customers or suppliers, but also financial institution (Meca and Timmer [2007]); nevertheless, it is known from a long time that the cash-to-cash cycle of companies, defined as

$$CCC = \text{Days of receivables} + \text{Days of inventory} - \text{Days of payables}, \tag{1.1}$$

is a truly comparative advantage, clearly related with the cash flow of the company and indirectly related to its size and WACC[9] (Randall and Farris II [2009]); however, it is only recently that literature focused on the exploitation of these differences from the whole supply chain point of view, increasing the value[10] for each supply chain partner involved (Randall and Farris II [2009]).

This broad concept is the base on which *Supply Chain Finance* (or Supply Chain Financing, SCF) emerges. A possible definition of SCF is provided by Pfohl and Gomm [2009]:

> Supply Chain Finance is the inter company optimization of financing as well as the integration of financing process with customers, suppliers, and service provider, in order to increase the value of all participating companies.

Anyway, in practical terms, it can be defined as:

> An approach that seeks to increase the value of two or more organizations, which are part of a supply chain, through the implementation of solutions that, exploiting the strength of the supply chain links, provide alternative means of financing; these solutions do not always require the presence of a financial institution, but may decrease the working capital and optimize the WACC.

The use of the term "Supply Chain Finance" can be traced back to the beginning of the 2000 (e.g.: Hartely-Urquhart [2000]). Originally the literature focused on the management and optimization of the so-called *Logistically induced financial flows* (Stemmler and Seuring [2003]), but evolved arriving to embracing the optimization of financial needs from the whole supply chain prospective for SMEs, as expressed by Xu and Zhong [2011], or for each size of enterprise, as expressed by Chen and Hu [2011]; both these concepts seem to provide a grip of the principle on which SCF solutions are proposed nowadays.

1.4.1 Players in the supply chain finance framework

The categories of players in the SCF framework do not always coincide with the ones of the typical supply chain context (Hofmann [2005]), therefore it's worth to list them:

Industrial and commercial companies The first typology of players are the firms that usually constitute the supply chain. The simplest interaction in the supply chain is between a supplier and its customer, where both can be an industrial as well as a commercial company.

[9] Weighted average cost of capital: $WACC = k_E \cdot E/(D+E) + k_D \cdot D/(D+E)$, where k_D is the cost of debt, k_E the cost of equity, D and E the book values of debt and equity.

[10] For the purpose of this work, a company value is defined as: $V = \sum_{t=0}^{\infty} \frac{NCF(t)}{(1+WACC)^t}$

Logistic Service Providers The second typology of players are the Logistic Service Providers (LSP): an LSP is defined as providers of logistics services that performs the logistics functions on behalf of their clients (Coyle et al. [2002]). LSP are not always considered members of the traditional supply chain framework (Hofmann [2005], Council [2012]), but they assume a more prominent role with the introduction of SCF: from general logistics service providers to administrative, SMEs guarantee, and even financial service providers (Ni-Na [2011], Xu and Zhong [2011], Chen and Hu [2011], Zhang and Yan [2009]).

Financial Institution and Investors The players in the supply chain finance context should be extended to include every actor that provide financial services, including both banks and private/public investors (Hofmann [2005]). The need for external financial service in SCF is widely recognized in literature, whether it is the need for a generic lender, as in Raghavan and Mishra [2009], or for a bank, as in Zhang and Yan [2009], Xu and Zhong [2011].

Internal new players As well as the introduction in the framework of new external actors, SCF calls for introducing also internal *micro-institutional* actors, i.e. department traditionally left out from the framework of supply chain (Hofmann [2005]): all departments dealing with financial activities should be included in a SCF framework.

1.4.2 General benefits of a Supply Chain Finance program

The benefits of an SCF program vary with the program itself. One of the main benefit according to literature is the improvement of the components of the CCC: it can be achieved through different SCF solutions, which also help improving the ability to forecast cash flows (Lamoureux and Evans [2011]). Another source of benefits, that can be reaped by enterprises with capital needs, comes from the adoption of solutions that optimize the WACC exploiting the links in the supply chain to obtain cheaper debt. If a financial institution is involved, it has the burden of collecting payments, optimizing the costs of such process, but it has benefits too: its revenues increase, as well as the certainty of payments, and it can implement a one-by-one risk assessment of SMEs (Xu and Zhong [2011], Hofmann [2005]). From a wider point of view, SCF programs provide better visibility on the supply chain, strengthening the links among partners, and offering new means of collaboration.

1.4.3 Typical solutions of SCF

As stated in Hofmann and Belin [2011], SCF solutions can be segmented through four dimensions: geographical aspects, payments methods, different types of platforms, and players involved. In this simplified framework, two of them are taken into consideration: players involved (mandatory presence of banks or similar financial institution), and payments method.

Mandatory presence of financial institution

Key account receivable sales program In the key account receivable sales program (called also *factoring*, as in Camerinelli [2008]), a group of supplier sells invoices issued to and approved by a trustworthy *key client* (called also *anchor buyer*) to a bank, in exchange of a percentage of its value; the bank will recuperate the entire invoice amount from the key client after the pre-established amount of time. Lamoureux and Evans [2011] presents also this type of program as SCF solution, further dividing it into pre-shipment (supplier payment by the bank trigged by the key customer order) and the more common post-shipment program (supplier payment trigged by invoice acceptance). Camerinelli [2008] as well lists both the alternatives under the SCF solutions, underlying the higher need for trustworthiness of the players and strength of the links in the supply chain that should characterize the pre-shipment alternative.

Sales Finance In the Sales finance, a supplier with a trusted portfolio of clients enable them to have extended payments terms, in exchange of becoming their preferential buyer (usually carried out with the support of a bank that acquire the discounted invoices from the suppliers and collect the inflated invoices from the clients, Dyckman [2011]).

Reverse Factoring In the reverse factoring, the flow of money and goods proceeds exactly as in the key account receivable sales program, but here is the bank (or the financial institution) that promotes the initiative proposing to the suppliers of the key client the acquisition of the account receivable for a discounted percentage that reflects the suppliers credit worthiness (Camerinelli [2008]).

Letter of credit A letter of credit is defined as[11]:

> an undertaking to pay in response to a documentary presentation.

In its common use (Mann [2000]), a buyer, in order to conclude a commercial transaction, asks to its bank (*issuing bank*) to issue a letter of credit to the bank of the supplier: if the letter is accepted by both banks, the issuing bank will pay the supplier (through its bank) for the amount specified in the letter, when the supplier will provide the necessary documentation (e.g.: documentation about the actual delivery, in its right amount and value, of the goods object of the transaction). This process is more common in international transactions (Camerinelli [2008]), and is a SCF solution if there is a decoupling in the payment to the supplier and the collection from the buyer.

Non-mandatory presence of financial institution

Trade Credit Trade Credit is a well-known managerial practice (Petersen and Rajan [1997], Biais and Gollier [1997]) in which a supplier allows a client to extend payments terms; it gained popularity also as SCF solution (Lee and Rhee [2011]), with a different modality, in which two parts involved in a business transaction may agree on payment terms usually composed by three terms: a discount percentage (e.g.: 2%), the period between which the client should pay to gain the discount (e.g.: 10 day), and the net day, on which the credit is due at most (e.g.: 30 days). In this way the client may decease its costs of good sold, and the supplier may decrease its CCC through a smaller receivable collection period.

Uniform Credit The uniform credit is a SCF solution in which a company receive money from a LSP, as a loan, pledging its inventories, and uses cash from sells of those inventories to repay the loan. This is one of the cases in which LSPs extend their roles from the mere transportation and warehousing (that is done anyway), to the procurement of financial services.

Alternative Financing Pfohl and Gomm [2009] propose this solution as mean of financing without have to recourse to financial institutions, but having capital coming from another player in the supply chain. Practically, the authors define the benefits of this type of program as the union of Supply Chain Benefits and Supply Chain Advantages: for a player N that needs a capital to undertake a project for which it has a demand, its supply chain partner G, their cost of capital i, they are defined as

- Supply Chain Benefits exist if the following equation stands

$$i_G < i_N \tag{1.2}$$

  or if the value of benefits G acquires if finances directly N's project are large enough to overcame the difference in costs of capital.

- Supply Chain Advantages exist if G has exclusive information or means of control over the project N is undertaking, or G can acquire information cheaper than N.

1.4.4 Expected future development of supply chain finance

SCF is a relatively new study field, both for academia and practitioners that want to propose or use such solutions. Future research in the area should focus first of all in gathering more data from the actual application of those programs (Pfohl and Gomm [2009]). Second, the tailoring of such solutions on the single company (Hofmann and Belin [2011]), detailing the benefits in function of the size, at first, and of other relative characteristic of firms entering those programs should be inquired. Third, the integration with other technologies, solutions, and managerial practices is far from being understood. Some author

[11] Uniform Commercial Code, § 5-102

proposed e-payable and e-invoice system as means of implementing effectively SCF solutions (Camerinelli [2008]), or at least that SCF needs an internet- or mobile-based system to implement effectively a SCF solution. This links should be inquired, as well as the links that may exists between SCF solutions and supply chain collaboration practices (like Vendor-Managed Inventories or Customer Replenishment Programs).

1.5 The financial performance

The concept of financial performance, or financial assessment, (specifically: of an enterprise) has been deeply analyzed by academic literature in the years. Different authors provides different ways of measuring financial performance: a single indicator can be provided (e.g.: Wagner et al. [2012]), or it can be identified through a list of indicators (e.g.: Lanier et al. [2010]).

1.5.1 Utility theory

However, even if a single indicator is provided, the financial performance is treated as an utility measure (let's call it *fp*), that is approximated by a function of different values, say $x_1, ..., x_n$:

$$fp = f(x_1, ..., x_n); \tag{1.3}$$

in case one indicator is provided, the utility measure will be a single cardinal value, in case more than one indicator is provided, the function that connects these indicators to the financial performance is not explicated. In the former case we can have simple approximations, like:

$$fp = \sum_{i=1}^{n} \omega_i \cdot x_i, \tag{1.4}$$

to more complex equation, such as (Kleijnen and Smits [2003])[12]:

$$fp = \prod_{i=1}^{n} x_i^{\omega_i}. \tag{1.5}$$

An example of the latter is Wagner et al. [2012], where the financial performance is:

$$fp = ROA = \frac{Net\ Operating\ Income}{Total\ Assets}. \tag{1.6}$$

In case more than one indicator is provided, they can be provided in more or less organized lists (such as the *balanced scorecard*) without formally explicating how they concur to the financial performance, or such link can be *suggested* through graphical means.

1.5.2 Graphical means

The most used graphical means to measure performance (included the financial performance) are Kiviat graph and spider charts (Kleijnen and Smits [2003]).

Kiviat graph

A Kiviat graph is a circular graphic technique to visual display system profiles; it has been developed in the 70's by Phil Kiviat, within the field of computer science (Morris [1974]). The process of developing a Kiviat graph follows a simple procedure:

1. Select an even number of performance indicators, half of which labeled as *good* (desirable), and half as *bad* (undesirable, or desirable as they decrease);

2. Divide a circle in as many segment as the performance indicators selected, and number the newly-created axes;

[12] Formally this second equation is equivalent to the first one to which a logarithmic transformation is applied

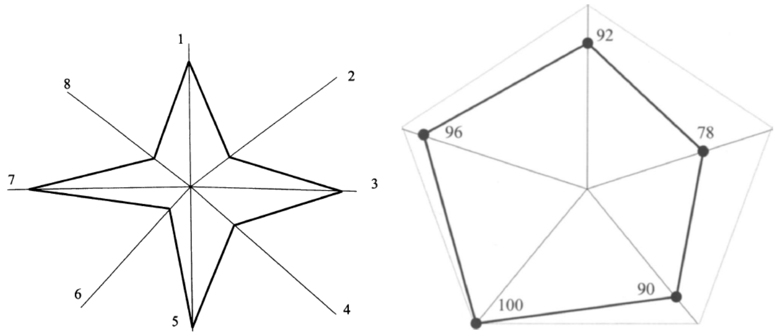
3. Plot the "good" indicators on the odd axes, and the "bad" indicators on the evens (Merrill [1974]).

Each axis of the Kiviat graph must be normalize to make the instrument meaningful. An example of Kiviat graph is presented in figure 1.11(a).

Spider chart

A spider chart[13] is a sequence of equi-angular spokes, called radii, with each spoke representing one of the variables. Practically speaking, it is a simple grids where the rays correspond to selected attribute (Vercellis [2009], Chambers et al. [1983]). Unless the Kiviat graph, no distinction is made upon "good" and "bad" indicators, but each axis should be normalized as well.

A spider chart is the generalization of a Kiviat graph. An example of spider chart is presented in figure 1.11(b).



(a) An example of Kiviat graph (b) An example of spider chart

Figure 1.11: Graphical means to measure the performance of a system.

Source: Kleijnen and Smits [2003].

Figure of merit

In both the Kiviat graph and the spider chart, the numerous values that constitute the graphical outcome can be reconnect to single outcome of the utility theory through a so-called *figure of merit* (FOM), that is, a function that transform the value on the axes of the charts in a single value, formally:

$$fp = FOM(x_1, ..., x_n) \tag{1.7}$$

Of course the figure of merit should be a function that maintains the indications provided by the charts, being them both positive or negative. The main figure of merit are:

$$FOM_{Kiviat} = \frac{\sum_{j=1}^{g} x_j - \sum_{k=1}^{b} x_k}{N} + 0.5; \quad FOM_{general} = \frac{1}{N}\sum_{i=1}^{N} x_i \cdot x_{i+1}; \tag{1.8}$$

where $i = 1, ..., N$ are the axes of the chart, and x_i is the value on the i-th axis; the first figure of merit is Kiviat-specific[14]: $j = 1, ..., g$ are the "good" axes, and $k = 1, ..., b$ are the "bad" one, with $N = g + b$, provided that each axis is normalized between 0 and 1; the second figure of merit can be used with both the instruments, applying the simple transformation of reversing the "bad" axes of the Kiviat graph. With axes normalized in the interval [0;1], both the figures of merit span in the same interval (Merrill [1974], Morris [1974]).

[13]Known also as: web, radar, star, or polar chart.

[14]A version of this figure of merit for the spider chart is the simple average of the scores of the axes.

1.5.3 Balanced scorecard

A balanced scorecard (Kaplan and Norton [1992]) is a tool that allows managers to focus on the measures that are more critical for their company, divided them into four areas: financial perspective, customer perspective, internal business perspective, and innovation and learning perspective. Inside each perspective, a list of measures is provided to the manager for monitoring bringing together disparate elements, avoiding sub-optimal decision based on limited knowledge, and allowing to reach the objectives in an effective way.

As regards this work, the noteworthy perspective is the financial one, that answers the question: *how do we look to shareholders*. There is not a set of standard financial measures, but each company is asked to chose the ones that best fit its needs, providing goals for each of one. An exemplificative set of measures is reported in table 1.4.

Measure	Goal
Cash Flow	Survive
Quarterly sales growth and operating income by division	Succeed
Increased market share and ROE	Prosper

Table 1.4: Example of financial prospective of a Balanced Scorecard.

Source: Kaplan and Norton [1992].

The financial perspective of the balanced scorecard is another example (after the graphical means) of financial performance estimation using more than one measure, for which the function that links the measures to the financial performance is not formally explicated.

1.5.4 Common measures of financial performance

The common measures used to estimate the financial performance of a company are numerous. Among the most common, the ones here reported are chosen because they fit the requirements of this work; they are based on the classification proposed by Azzone [2006] (that is also the reference for this section), that divides the financial-based indicators regarding to two dimensions: logic (accrual or financial), and measurement unit (absolute or monetary value); the main indicator are reported in table 1.5.

	Income (accrual)	Cash
Absolute value	ROE, ROI, ROA, ROS, ROCE, RONA, ROIC	CFRoi, EM
Monetary value	RI, EVA	Cash EVA, CVA

Table 1.5: Main indicator of financial performance.

Source: Azzone [2006].

Their relative metrics are[15]:

- Return on Equity: $ROE = \dfrac{Net\ Operating\ Income}{Equity}$
- Return on Investments: $ROI = \dfrac{Net\ Operating\ Income}{Investments}$
- Return on Assets: $ROA = \dfrac{Net\ Operating\ Income}{Total\ Assets}$
- Return on Sales: $ROS = \dfrac{Net\ Operating\ Income}{Sales}$

[15] Where k is a generic measure of the cost of capital, $WACC$ is the weighted average cost of capital, $NOPAT$ is the net operating profit after tax, DA are the depreciation and amortization, and $CFFO$ is the cash flow from operating activities.

- Return on Capital Employed: $ROCE = \frac{Net\ Operating\ Income}{Total\ Assets - Current\ Liabilities}$
- Return on Net Assets: $RONA = \frac{Operating\ Income + DA - Taxes}{Fixed\ Assets + OWC}$
- Return on Invested Capital: $ROIC = \frac{Operating\ Income\ After\ Tax}{Fixed\ Assets + OWC}$
- Residual Income: $RI = Operating\ Income - k \cdot Investments$
- Economic Value Added: $EVA = NOPAT - WACC \cdot (Total\ Assets - Current\ Liabilities)$
- Cash Flow Roi: $CFRoi = \frac{CFFO}{Market\ Value\ of\ Invested\ Capital}$
- Economic Margin: $EM = \frac{CFFO}{Invested\ Capital} - k$
- Cash EVA: $CashEVA = Operating\ Cash\ Flow - WACC \cdot Invested\ Capital$
- Cash Value Added: $CVA = Operating\ Cash\ Flow - Required\ Cash\ Flow$

1.6 Financial Assessment of a Supply Chain

The financial assessment of a supply chain is a topic not as well developed as the financial assessment of a single enterprise. However, contributions on the matter do exist, usually within broader topics such as extension of balance scorecard approaches to the supply chain as a whole, performance measures for supply chain simulation scenarios, and in general performance measures systems that takes into consideration the entire supply chain.

Nevertheless, these contributions are based on the characteristics of supply chain presented previously, and they share the same characteristics: even if they takes into consideration the supply chain, they are enterprise-centric, providing measures that are specific of the single company and its supply chain: company that produce the same product, using the same materials, selling it to the same pool of customers will have different values for the same indicators, if not different metrics or indicators thereof.

The contributions of this matter can be divided into two groups:

- Contributions that assess the financial performance of a company's supply chain;
- Contributions that assess the financial performance of companies within a supply chain, usually against one or more determinants.

In the first categories we find the contributions more relevant for this work, such as the SCOR model, and in general the supply chain performance measurement systems; of course the second category is of less interest for this work, buy may contain useful indications as well.

1.6.1 Supply chain performance measurement systems

Estampe et al. [2010] mapped 16 supply chain performance measurement systems; among them, some present relevant features from the point of view of the supply chain financial assessment, other are less relevant, or too much specifically focused on other aspects. Among the relevant one, we can cite the SCOR model, the ABC (Activity-based costing), the already mentioned balanced scorecard (addressing the supply chain as a whole), and the strategic profit model; other model (usually commercial ones) present relevant features, but are usually strongly overlaps, from the financial performance point of view, with the one mentioned, and will not be analyzed in the detail.

The SCOR model

The Supply Chain Operations Reference (SCOR [2008]) is a model, developed by the Supply Chain Council, for evaluating and comparing supply-chain activities and performance: it provides a unique framework that links business process, metrics, best practices and technology into a unified structure. One of the advantages of the SCOR model is that it provides common metrics, benchmarks, best practices, and standard terminologies (Huan et al. [2004]).

It is divided into five primary management processes: Plan, Source, Make, Deliver, and Return, and consider two tiers of suppliers and customers around a focal company. The graphical representation of the model is presented in figure 1.12. The model is divided into four hierarchical levels, reported in table 1.6.

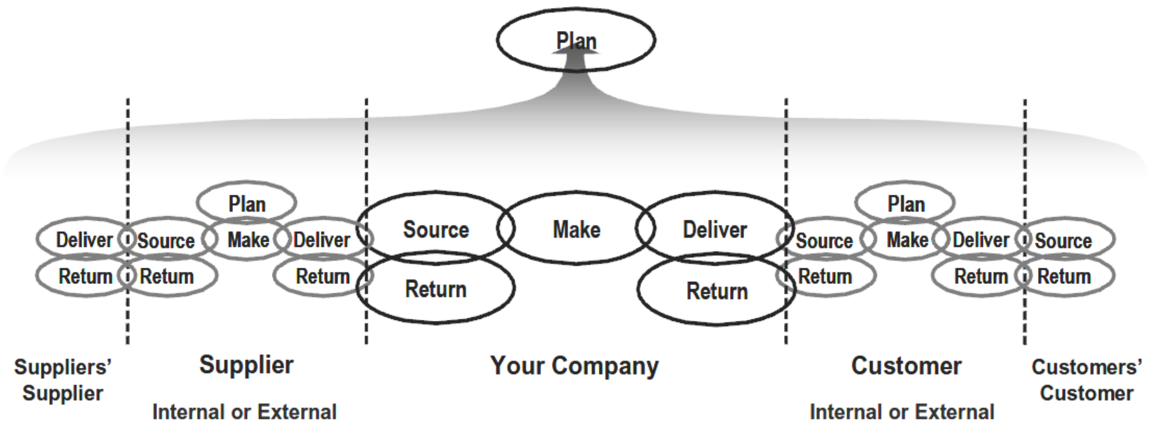


Figure 1.12: The classical representation of a general SCOR model.

Source: SCOR [2008].

Level	Name	Description
1	Top Level (process type)	Defines the scope and content of the SCOR model: here performance targets are set.
2	Configuration Level (process categories)	A company's supply chain is configured through core process categories.
3	Process element level (decompose process)	Defines the company's ability to compete successfully in its chose market.
4	Implementation level (decompose process element)	Specific practices are implemented by each company; not in the scope of the model.

Table 1.6: Levels of SCOR model.

Adapted from: SCOR [2008].

Practically speaking, the SCOR model provides measures and metrics that are hierarchically decomposable: level 1 includes strategic metrics, that are few, of high level, and holistic, and those strategic metrics are broken-down in the other levels. The metrics are declined in the proper processes: the process of "source" will have a strategic metrics, and the more detailed process of "source stocked products" will have metrics hierarchically decomposed from the strategic ones. An example of metrics hierarchical breakdown is reported in figure 1.13. The main SCOR measures related to the financial performance of a company's supply chain are summarized in table 1.7.

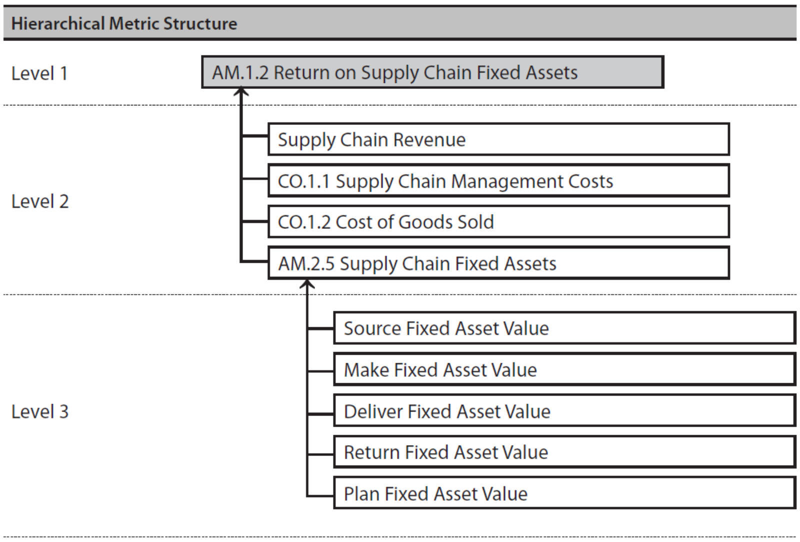


Figure 1.13: An example of metrics hierarchical breakdown.

Source: SCOR [2008].

Name	Formula
Total Supply Chain Management Cost	$TSCMC = Sales - Profit - Service\ Costs$
Cost of Good Sold	$COGS = Direct\ materials + Direct\ labor + Indirect\ Production\ costs$
Cash to Cash Cycle	$CCC = Days\ of\ receivables + Days\ of\ inventories - Days\ of\ payables$
Return on Supply Chain Fixed Assets	$RSCFA = \frac{SC\ revenues - COGS - SC\ management\ costs}{Supply\ Chain\ Fixed\ Assets}$
Return on Working Capital	$ROWC = \frac{SC\ revenues - COGS - SC\ management\ costs}{Inventory + Accounts\ Receivable - Accounts\ Payable}$

Table 1.7: Main supply chain measures related to financial performance in SCOR model.

Source: SCOR [2008].

Balanced scorecard

The balanced scorecard, presented above, has been applied, in some literature contribution, to the supply chain as a whole, especially from the beginning of the 2000th. Among the financial performance measures selected in literature, the most relevant are summarized in table 1.8.

Strategic profit model

The strategic profit model is a tool that assesses the financial performance of a company measuring how efficiently a firm manufactures and sells its product, through the basic equation (Stock and Lambert [2001]):

$$ROE = ROA \cdot Equity\ Multiplier = \frac{NOI}{Total\ Assets} \cdot \frac{Total\ Assets}{Equity} \tag{1.9}$$

Further developing those equation allows to increase the detail of the analysis of the determinants of the financial performance of the company. As shown by Stapleton et al. [2002], the model can be applied to understand the performance of a company's supply chain.

Measure	Contribution
Profit	Park et al. [2005]
Profit Margin	Brewer and Speh [2000]
CCC	Brewer and Speh [2000], Bullinger et al. [2002]
Profitability	Brewer and Speh [2000]
ROA (SC)	Brewer and Speh [2000]
SC cost	Park et al. [2005], Bullinger et al. [2002]
SC inventories	Bullinger et al. [2002]
SC revenues	Bullinger et al. [2002]
ROI	Bullinger et al. [2002], Bhagwat and Sharma [2007]
ROCE	Bullinger et al. [2002]
Revenues	Park et al. [2005]
Revenues growth	Park et al. [2005]
Cash Flow	Park et al. [2005]

Table 1.8: Measures used in financial perspective of supply chain-focused balanced scorecard.

1.6.2 Other relevant contributions

Lanier et al. [2010]

One interesting contribution comes from Lanier et al. [2010], that approaches the problem of measuring the financial performance of a so-called *concentrated supply chain*, a supply chain formed by three companies where the first make at least 10% of revenues selling to the second, that in turn does the same with the third. The chain-level metrics proposed by the authors are reported in table 1.9.

Measure	Metric [1]
Return on Assets	$ROA = \frac{\sum_{i=1}^{3} NOI_i}{\sum_{i=1}^{3} Total\ Assets_i}$
Margin	$M = \frac{\sum_{i=1}^{3} NOI_i}{\sum_{i=1}^{3} ExSales_i}$
Asset turnover	$AT = \frac{\sum_{i=1}^{3} ExSales_i}{\sum_{i=1}^{3} TotalAssets_i}$
Cash-to-cash cycle	$CCC = \sum_{i=1}^{3} DoR_i + DoI_i + DoP_i$

[1] *NOI*: Net Operating Income; *ExSales*: sales outside the chain.

Table 1.9: Chain-level metrics in Lanier et al. [2010].

Camerinelli and Cantù [2006]

One noteworthy contribution is provided by Camerinelli and Cantù [2006], that states how the supply chain performance is linked to the financial performance of the companies involved. The authors proposed to assess the supply chain financial performance using measures that:

> External stakeholders, analysts, and venture capital firm take into consideration when evaluating a firm

The measures proposed are:

- Total supply chain cost

- Service level
- Inventory
- Cash-to-cash cycle

Moreover, the authors propose to use also the Economic Value Added (EVA), whose metric has already been proposed.

Other relevant contributions

Other relevant contribution in the filed of the financial assessment for supply chain are summarized, by measure prosed, in table 1.10

Measure	Contribution
ROI	Christensen et al. [2007], Vickery et al. [2003]
ROA	Vickery et al. [2003]
ROS	Vickery et al. [2003]
Profit	Christensen et al. [2007], Beamon [1999], Lapide [2000]
Revenues	Beamon [1999], Lapide [2000]
Total cost	Beamon [1999], Lapide [2000]
Cost per unit	Morgan [2004], Beamon [1999], Lapide [2000]
Inventory carrying cost	Morgan [2004]
Cash flow	Lapide [2000], Gunasekaran et al. [2001]

Table 1.10: Other relevant measures from academic literature.

1.7 A literature drill-down: the mechanical indusrty

1.7.1 Definition of mechanical industry in Italy

Different authors provide different definitions and boundaries for the mechanical industry in Italy. The definition depends in part on the type of analysis that has to be done and in part on the data used. Russo et al. [2006] state that, excluded surveys, there are only three types of data available, with different horizon and focus (summarized in table 1.11): censuses (usually by Istat), data about firms' exportation from Istat, and the database of firms' balance sheets managed by Aida Van Djick.

	Horizon	Focus	Data
Censuses (Istat)	1991-2001	Comunal	Size, no. of firms, level of employment
Exportation	TBD	Regional	Exports value and amount
AIDA	TBD-2011	Single firm	Balance sheet, income statement, geographic position, sector of activity, level of employment

Table 1.11: Type of data available for analyses in the mechanical industry

Besides the type of data used, most of the literature defines the mechanical sector selecting codes from one of the most recent edition of the ATECO codification system (1991, 2002, 2007). Some codes seem to be more present than others: they can be defined as a sort of "core components" of the mechanical industry, and papers can be analyzed by differences from them; these codes are summarized in table 1.12[16].

[16]The core codes are expressed in 2002 Ateco codification, that is the most used in the paper currently available; only minor changes have been made in those codes in the passage from ATECO '91 and 2002, and ATECO

ATECO Code	Description
DJ	Metallurgy and manufacture of metal products
DK	Manufacture of machinery and equipment
DL	Manufacture of electrical machinery and electrical, electronic and optical equipment
DM	Manufacture of transportation means

Table 1.12: "Core" Ateco codes in the definition of the mechanical industry

Russo et al. [2006] decided to focus on Istat data about *Local System of Labor, "SLL"* for 1991 and 2001[17] (that falls into the censuses category). Those data provide an analysis of Italian geographic zones clustered by socio-economical characteristics. In particular the paper focuses on the "mechanical industrial districts", that are SLLs characterized by an higher-than-the-average level of manufacturing production. Selecting the district of the mechanic industry, the authors, *de facto*, accept the definition given by Istat, that includes the ATECO codes (codification '91) in table 1.13.

ATECO Code	Description
29	Manufacture of machinery and mechanical appliances
DL	Manufacture of electrical machinery and optical and electrical equipment
28	Manufacture of fabricated metal products
27.5	Metals melting

Table 1.13: Definition of mechanical industry by ISTAT, used by Russo, Pirani, and Pratelini (2006)

Similarly, Ferri and Ventura [2007] used censuses, in particular Istat *Censimenti dell'industria e delle Attività Produttive*, 2001, but they actively filtered the ATECO codes (again codification '91) selecting the sectors of interest, narrowing each sector to a precise type of manufacturing; their selection is summarized in table 1.14[18].

ATECO Code	Description	Reference customers
29530	Manufacture of machinery and equipment for food processing and production	Food
29541	Manufacture of machinery and equipment for textile processes	Apparel
29542	Manufacture of machinery and equipment for leather and footwear industries	Leather and footwear
29564	Manufacture of machinery for wood treatment and similar processes	Furniture

Table 1.14: Definition of mechanical industry by Ferri, and Ventura (2007)

MetalNet, a project of the University of Modena and Reggio Emilia (2005), aims at monitoring the changes and dynamics in the mechanical industry, and uses as well censuses, selecting firms with the ATECO codes (codification 2002) that correspond to the "core" code already showed[19].

2002 and 2007. For further information cf. Vicari et al. [2009] and Puglisi et al. [2003] (in Italian), or the URL http://www.istat.it/it/archivio/17888; high level Ateco codes correspond to the codification NACE, by Eurostat (in English), cf. NACE [2012].

[17] cf.: Distretti e SSL Giovannetti et al. [2005].

[18] "Reference customers" means the industrial district within which firms of the mechanical industry sell their product (i.e: "Food" -> the code refers to producers of machineries for food treatment).

[19] Excluded the code 33.1: Manufacture of medical equipment, dental, and orthopedic implant.

As minor source (in terms of part of work devoted specifically to the mechanical industry), Chiarvesio et al. [2005] used a survey to gather data, using ATECO ('91) codes to select the sectors of interest: they narrow the code DJ to the only *28: Manufacture of fabricated metal products*, and the DK to *29: Manufacture of machinery and mechanical appliances*.

To conclude, the Joint National Observatory of Federmeccanica, in its more recent report about the mechanical industry (2001) defines it with the "core" ATECO codes (codification '91), plus the code *453: Installation of services in buildings*.

1.7.2 The importance of the mechanical industry in Italy

The importance of the mechanical industry for the Italian economy is well documented. It is considered paramount for the overall economy given its importance in terms of employment, and its contribute to Italian export (ASTER workgroup, 2003, Russo et al. [2006], Ferri and Ventura [2007]).

ISTAT Data about exportation Most of the authors (e.g..: Margnini and Gilodi [2009], Bocconcelli and Pagano [2011]) quote ISTAT data to support their assumption about the importance of the sector for the Italian economy. The last data available about Italian exportation and importation in Italy in 2010, the mechanical industry[20] contributed for about the 28% of the total intra-EU Italian exportation, and with the 31% of the Italian world exportation. It was also characterized by a positive balance of payments, of around 41 billion €. In both cases those values overcome the other aggregate sectors.

In the ATECO codification system, the mechanical industry is part of the manufacturing sector. Also inside the manufacturing sector, the mechanical industry is the first sector in terms of export, with about the 21% of the total manufacturing exportation. Considering the balance of payments, it has the highest value in the manufacturing sector.

ICE report Another source of information, sometimes quoted by authors Ferri and Ventura [2007], is the set of annual reports by ICE[21]. The last report available (2011) sustains that the mechanical industry is one of the specialized sector in which the normalized balance of payments[22] recorded an increase in 2011. In particular, in terms of European market share, the mechanical industry showed an increase from the so-called *pre-crisis* level; on the other side, the report underlines that those data cannot be read separately from the decrease in the demand seen by the European Union in the last three years.

In general terms, the quota of machineries exportation in Italy suffered from the general decrease in the demand, but some "new market" like China, India, and Brazil showed promising and increasing levels of demand.

1.8 The mechanical industry object of this work

The next sections present relevant contributions about the technical aspects that lay beyond the two sub-groups of the mechanical industry in Italy object of this work. They are:

- Manufacture of tube;
- Manufacture of machinery for the food industry.

1.8.1 Manufacture of tubes

Tubes in the modern times are paramount, and the literature treating their manufacture and usage is abundant and deeps every aspect. Tubes are used to transport water from the sources of water supply to

[20] In this case identified through the ATECO codes (codification 2007) 25: "Manufacture of fabricated metal products, except machinery and equipment" and 28: "Manufacture of machinery and equipment n.e.c.".

[21] Istituto per il Commercio Estero, *Institution for international commerce*, part of ISTAT.

[22] In a generic sector, the normalized balance of payment is:

$$\frac{Export - Import}{Export + Import}$$

the points of distribution, convey waste from civil facilities to points of treatment, carry crude oil, and in general liquids, chemicals, mixtures, gases, vapors, and solids that well fit this mean of transportation from a location to another. A part from the industrial and civil usage, tubes play a critical role in the safety of our cities, being a fundamental part of fire protection systems and health facilities.

A *tube* is defined (cfr.: Nayyar [2000], Bralla [2007], Antaki [2003]) as an hollow product of round or any other cross section having a continuous periphery. Round tube size may be specified with respect to any two, but not all three, of outside diameter, inside diameter, or wall thickness. A *pipe*, although the difference is minimal, is defined as a tube with always a round cross section conforming to standardized dimensional requirements. A tube (or a pipe) is the principal component of a *piping* system, a network composed by fittings, flanges, valves, and other components to allow the usages showed above. The main components of a piping system are presented in the following paragraphs.

Tubing

Tubes that fall into the mechanical industry umbrella can be characterized by two dimensions:

- Raw material: steel, cast iron, and aluminum;
- Production process: seamless, welded, molded, and so on.

The raw material of steel is iron, that usually sustains the processes of *sintering* or *smelting*, which output is the basic component of the steel-making process (for more detail about these processes more specific literature can be consulted: Gupta et al. [2009], DeGarmo et al. [2007]). The production of cast iron proceed of course from iron as well; four type of cast iron are produced: white, gray, ductile and malleable iron. Aluminum for tubes may be up to 99% pure aluminum to aluminum alloy with other element such as copper, manganese, silicon, zinc, and so on.

The types of materials utilized in the production of tubes analyzed in this work are summarized in figure 1.14.

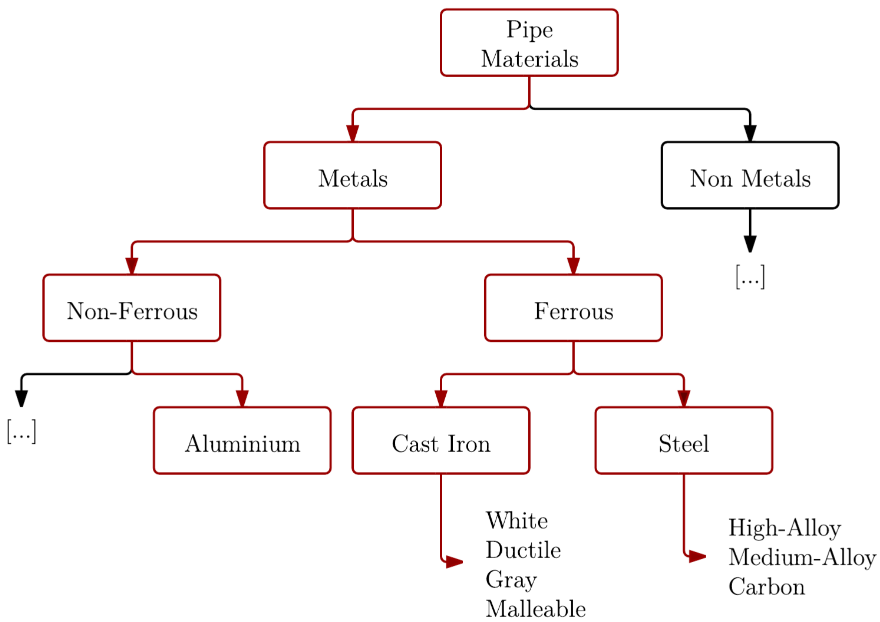


Figure 1.14: Main materials of tubes considered in this work.

Source: adapted from Antaki [2003].

As regards the types of production, the distinction is made upon the typology of tube produced, that can be seamless or welded, where seamless are characterized by the absence of joint and welded seam along the tube, while welded are by their presence; cast iron tube are instead produced during the casting process, through the use of molds.

Seamless tube Seamless tube are manufactured by first producing a hollow tube which is larger in diameter and thickness than the final tube. Usually the so-called Mannesmann rotary piercing process is used (see fig. 1.15); when this first tube has be processed, different processes are applied to acquire the final tube: techniques such as the Mannesmann process itself, suitable for small (6 to 90 mm of nominal diameter) and medium (90 to 200 mm) size, are economical inapplicable to large size (nominal diameter from 250 to 700 mm), where usually the pipe are extruded or forged (if also of large thickness).

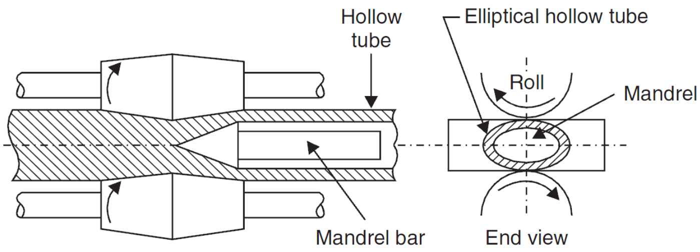


Figure 1.15: The Mannesmann process for tube making.

Source: Gupta et al. [2009].

Welded tube Welded tube are produced by forming a cylinder from flat steel sheets. The type of process is a function of the diameter: for small (nominal) diameter, the furnace-welded process is applied. For larger diameter, the joint is made by fusion, and the most known process is the Electrical Resistance-Welded (ERW) pipe, in which the strip is progressively bended until it is of circular form and then welded electrically. The ERW process is a part of the so-called *innovative* production processes, that in general comprises cold forming, forging and wire drawing.

Cast iron tube Cast iron tubes are formed through four processes: vertical pit casting, horizontal casting, centrifucal sand mold casting, and centrifugal metal mold casting; in each of those processes the tube is formed through the use of a mold. Cast iron tubes are characterized by a long life expectancy, and for this reason are commonly used for gas distribution systems and underwater piping.

The typology of tubes and pipes considered in this work are summarized in table 1.15.

	Seamless (extrusion)	Welded	Innovative Cold Forming/Forging, Drawing	Casted
Steel	X	X	X	
Aluminum	X	X		
Cast Iron				X

Table 1.15: Summary of the typology of tubes and pipes divided by raw materials and production process.

Fittings

A fitting is a component used to connect straight segment of tubes, as well as modify their size and shape. Fittings are usually produced with the same material of the main pipe, and the main typologies are: elbows, tees, reducers, crosses, and laterals. Fittings are commonly forged, and standardized through specifications of the dimensions in function of the nominal pipe size. An example of fittings is provided in figure 1.16.

1.8.2 Manufacture of machinery for the food industry

The field of manufacturing of machinery for the food industry can be divided into ten categories (Saravacos and Kostaropoulos [2005]), hierarchically summarized in figure 1.17; the main categories are analyzed from the point of view of their importance respect to the mechanical industry.

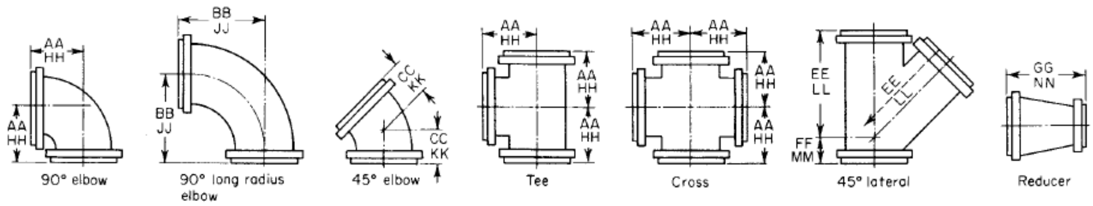


Figure 1.16: Example of tube fittings (specifically: commercial cast-steel flanged fittings).

Source: Nayyar [2000].

Mechanical transport and storage The mechanical transport of food materials is divided into fluid and solid transport. The fluid transport usually is based on systems of pumps and piping, while the solid transport is usually carried out through hydraulic, pneumatic, or conveyors systems. Food storage is divided into large and small size: large size contains silos and tanks, while small size contains pallets, boxes, bags, an vats. The material used for each of them are summarized in table 1.16 (Heldman and Lund [2007]).

Food storage container	Construction material
Silos	Steel, aluminum
Tanks	Wood, steel, concrete
Pallet	Wood, aluminum
Boxes	Wood, different metals
Vats	Stainless steel
Bags	Fiber carton, other materials, no metals

Table 1.16: Construction materials for food storage equipments.

Source: Saravacos and Kostaropoulos [2005], Heldman and Lund [2007].

Mechanical processing equipment The mechanical processing of food is divided into size reduction, size enlargement, homogenization, and mixing and forming. Size reduction is applied to solid, and is divided into cutting, crushing, and grinding; all of these categories requires complex equipment, with a great deal of metal structures, engines, and blades. The size enlargement is divided into free structure agglomeration and compression; in both cases the principle construction material is some kind of metal. Homogenization deals with size reduction of liquid; it can be achieved through pressure or rotators, that both requires an engine, or through more complex systems based on ultrasonic emissions. Mixing requires different equipment based on the state of matters involved (solid/solid, solid/liquid, and so on), however, any mixer requires an engine, and sometimes a couple or more blades; forming equipment are usually composed by extruded or molded metal components. (Saravacos and Kostaropoulos [2005])

Mechanical separation The food mechanical separation varies greatly for different states of the matter. In general terms, solid/solid separation involves the use of blades, while other types of separations involve the use of filters, presses, scrubbers, and other equipment. The separation regarding solid food includes also the removal of food-related parts; these practices, especially the latter, requires complex systems, usually with blades and at least one engine, often built through the use of metal structure; an example of food separation system that requires a metal structure is reported in figure 1.18.

Heat transfer and thermal processes Transferring heat to food requires special equipment, depending on the characteristics of the food and the requirements of the process. A classification would be too much burdensome; therefore, a high-level brief analysis of food heat transfer components is provided:

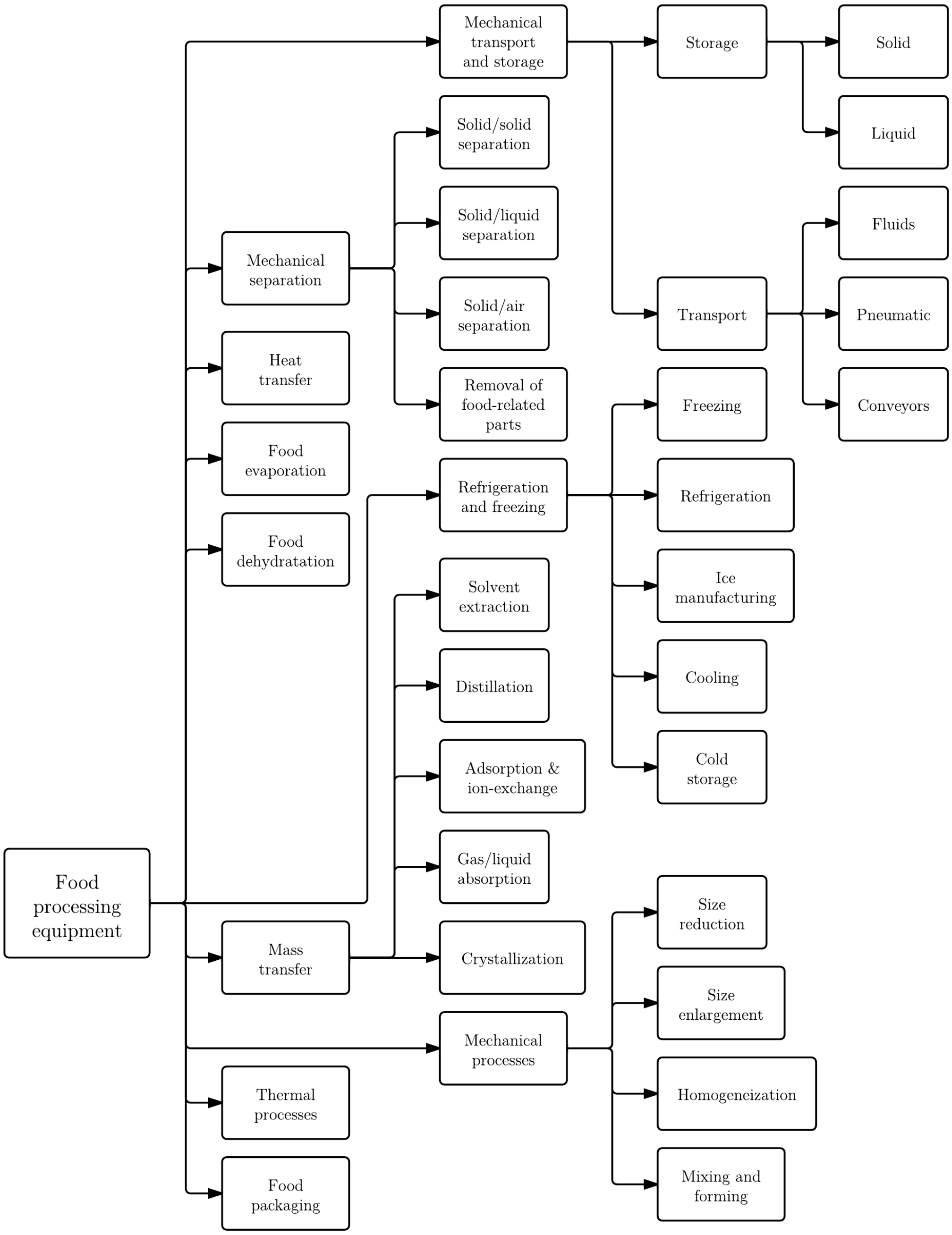


Figure 1.17: The ten main categories of machinery for the food industry.

Source: adapted from Saravacos and Kostaropoulos [2005].

- Shell-and-tube exchangers: characterized by a low heat transfer surface area per unit volume, are composed by a shell and a piping system to convey heat;
- Compact exchangers (including plate exchangers): characterized by an high heat transfer surface area per unit volume, divided in different categories based on the construction specification; most of them requires more or less complex piping systems, as well as metal structures. (Rohsenow et al. [1998])

Food evaporation Food evaporation is a subset of the heat transfer category; from the material point of view (specifically what regards the mechanical industry), food evaporators do not differ from the

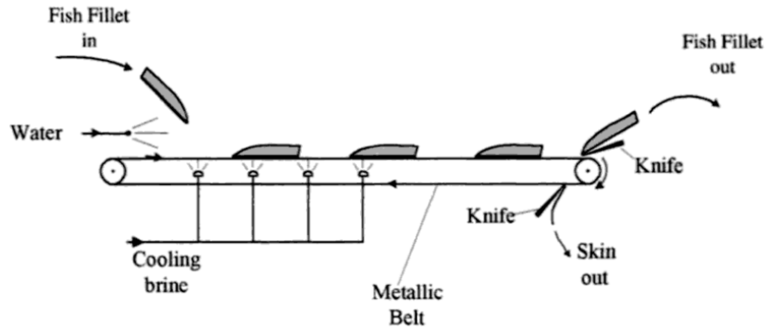


Figure 1.18: An example of part-related solid food separation: skin removal from fish fillet.

Source: Saravacos and Kostaropoulos [2005].

generic heat exchangers.

Food dehydration Food dehydration is a technique mainly related to food preservation. Food dryers are of different complexity, from solar to tower dryers to conveyor belt, but in general terms rely strongly on the use of metal structures, and in the more complex model on engines.

Refrigeration and freezing equipment Refrigeration (divided in cooling, above 0°C, and freezing, under 0°C) is a process for the preservation and the low-temperature manufacturing of food. There are different methods of refrigeration: mechanical compression, physical-chemical methods, direct evaporation, and electrical methods. Compressor for refrigeration processes rely heavily on output from the mechanical industry, including piping systems, that are present also in evaporators and condensers. The ice manufacturing process is different, but it actually rely as well on a piping system.

Food packaging Food packaging should answer to a series of requirements: beyond the usual requirements of industrial packaging, safety and health requirements are added. Contrary to the other categories, within packaging the metal is used also as component of the final product and not only as part of the equipment used. The main metal used in food packaging is aluminum (especially cans), with tin and chromium. (Saravacos and Kostaropoulos [2005])

A final remark on the construction materials As can be understood, the construction of machinery for the food industry revolves around metals. In particular, the most used material for machinery parts that come in contact with food is stainless steel. Materials used are summarized in table 1.17.

Metal	Usage
Carbon and low-alloys steel	Mills, presses, oil tanks at high temperatures
Stainless steel	General direct contact with food
Aluminum	Food freezing, packaging
Copper	Fermentation, chocolate manufacturing
Cast iron	Supporting purposes, parts with no direct contact with food
Tin	To avoid direct contact of food with other materials, packaging
Chromium	Where stainless steel is unsuitable, packaging

Table 1.17: Summary of metals used in food equipment construction

Adapted from: Saravacos and Kostaropoulos [2005], Heldman and Lund [2007].

Chapter 2

Objectives and Methodology

This chapter illustrates, in its first part, the objectives of the work, in the form of its research questions; this is followed by the methodology section, that contains the steps undertook to develop the model, the methodology used to treat the data, and methodological notes about the model and its application.

2.1 Objectives

The objectives of this work can be effectively summarized in three research questions. Such questions compose the research framework of this work. The research framework is also represented in figure 2.1.

RQ 1. **The financial assessment of a supply chain**

- *What does it mean to financially assess a whole supply chain? How does this concept differs from the financial assessment of a single organization?*
- *What are possible choices of drivers that might suit the needs for the financial assessment of a supply chain?*

As showed in the literature review, the financial assessment of a supply chain is a concept that finds few academic contributions. Therefore, this question aims at developing a formal definition of financial assessment for a supply chain, providing a choice of measures and functions for the practical financial assessment of a supply chain.

RQ 2. **Financial assessment and supply chain profiling**

- *Are there more effective ways to represent a supply chain, in relation with its financial assessment?*
- *Is there a link between the representation methodology and the effectiveness of the financial assessment of a supply chain? Can a correct representation of a supply chain be part and parcel of its financial assessment?*

The supply chain profiling is a concept that finds application in many different topics, and benefit from an effective representation methodology. This question aims at inquiring if the financial assessment of a supply chain is affected by the way in which the supply chain is represented, and if a more effective way to represent it in relation with its financial assessment exists.

RQ 3. **Financial assessment and supply chain finance**

- *Are there links between the financial assessment of a supply chain and an effective application of financing solution, and in particular of non-canonical financing solution, such as solutions of Supply Chain Finance?*
- *How the different financial performance of supply chain nodes affects the implementation of non-canonical financing solutions?*

This third questions wishes to analyze the financial assessment methodology in terms of possible application of SCF solutions to a whole supply chain: possible roles for organizations within a specific node, areas of interest for particular sets of solutions, and, more in general, indications for effective implementations of those solutions based on the financial characteristics of the supply chain nodes. Moreover, it wants to analyze the differences in the application of SCF solutions to a whole supply chain, respect to a mere group of organizations.

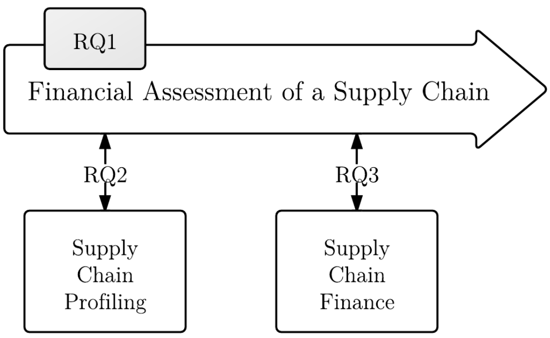


Figure 2.1: The research framework.

2.2 Methodology

The model object of this work as been developed concurrently and recursively within a consulting project [...] in which two distinct, but interconnected, parts of the mechanical supply chain in Italy have been analyzed. Such parts, that can be considered supply chain as well, are the *manufacture of tubes* and *machinery for the food, beverage, and tobacco industry.* The methodology followed, although its recursive nature, can be divided in seven steps, graphically represented in figure 2.2:

1. Analysis of secondary sources regarding the mechanical industry in Italy;
2. Selection of the two sub-group of the mechanical industry object of the model application (namely, the manufacture of tubes and of machinery for the food industry supply chains);
3. Selection of the ATECO codes that will be object of the analysis, following the methodology presented later in this chapter;
4. Analysis of the quantitative data of the firms belonging to the ATECO codes selected;
5. Identification and interview of relevant players in the two sub-groups: practitioners, professors, associations, experts;
6. Development of the supply chain representation, and of its financial assessment, for the two supply chains;
7. Generalization of the supply chain representation and financial assessment methodology and model.

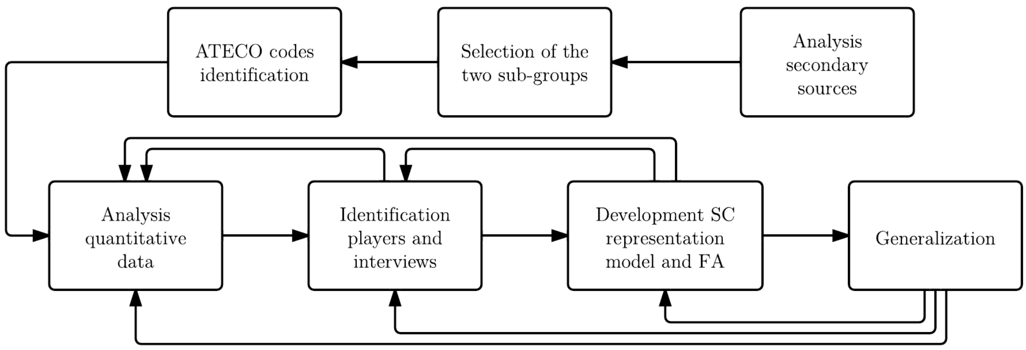


Figure 2.2: The recursive steps of the methodology followed in the development of this work.

The remaining sections of this chapter will analyze the methodology adopted to develop this work, in the order in which they are presented in the work itself: first the literature review, then the model, and the model application.

2.2.1 Literature review

The literature review covered a paramount role in the development of the model. Given the applicative nature of the methodology that was followed to develop this model, secondary sources were needed to build an understanding of the supply chain object of this work, that was found especially useful in the model application part. The references for this work can be divided in: journal articles, books or book chapters, reports (technical reports, manuals, and so on), unpublished articles (conference proceedings and lecture notes), patents, and other sources (mainly electronic resources). As regards the journal articles, the main sources were:

- Journal of Operations Management, (4);
- The International Journal of Logistics Management, (3);
- Journal of Business logistics, (3);

- Supply Chain Management: An International Journal, (3);
- International Journal of Physical Distribution & Logistics Management, (3);
- European Journal of Operational Research, (3);
- Simulation Modelling Practice and Theory, (2);
- International Journal of Operations & Production Management, (2);
- STRATEGY AND BUSINESS, (2);
- Review of Financial Studies, (2);
- ACM SIGMETRICS - Performance Evaluation Review, (2);
- Fifty-one other sources with one single contribution.

The subdivision of contribution per category of source is reported in figure 2.3.

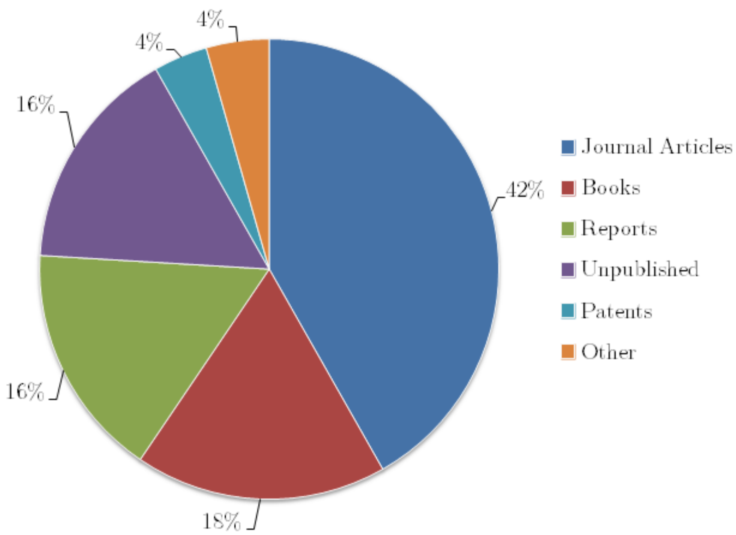


Figure 2.3: Work reference per contribution source.

2.2.2 Model development

The model developed in this work is composed by three main outputs: the supply chain flowchart, the node exchanges matrix, and the financial assessment tool.

The supply chain flowchart has been developed using components typical of the well-known flowcharting technique[1]; the components have been designed using the tool *lucidchart*[2]. As regard the node exchanges matrix, and the consequent production coefficients matrix, they represent an adaptation of the Leontief's economic model (Leontief [1986], Jensen [2001]) to a supply chain context.

2.2.3 Model application: quantitative data

The main source of quantitative data is represented by the Aida on-line database; multiple extraction have been carried out, with the same template: extracted columns represent attribute (numerical value such as *revenues* or indicators, or categorical values like Italian region), while extracted rows represent

[1]Cf.: IBM [1985], ECMA [1966]
[2]Cf.: `www.lucidchart.org`.

observation, each for every firm. Formally, the entire set of extraction from the on-line database can be called $\mathcal{D}$, and is composed by m observations and n attributes; its formal representation is[3][4]:

$$\mathbf{X} = [x_{(ij)}],\ i \in \mathcal{M} = \{1, 2, ..., m\},\ j \in \mathcal{N} = \{1, 2, ..., n\}, \tag{2.1}$$

where the i-th observation and the j-th attribute are expressed as:

$$\mathbf{x}_i = (x_{i1}, x_{i2}, ..., x_{in}) \tag{2.2}$$
$$\mathbf{a}_j = (x_{1j}, x_{2j}, ..., x_{mj}). \tag{2.3}$$

As stated in Vercellis [2009], in order to perform operation of data mining, pattern recognition, and similar activities, the data should be prepared, to increase reliability, and explored, to highlight relevant features and help the successive phases.

2.2.4 Data Preparation

Data preparation is a set of procedures that aim at dealing with three data problems: incompleteness, noise (caused by outliers), and inconsistency. As regard the first, results from the Aida on-line database present some missing data, distributed quite evenly among the observation, but very asymmetrically among the attributes: some attributes like revenues, ebit, and so on, have an almost 0% of missing value, while attributes of more detailed balance sheet items (e.g.: *plant and expansion costs*, under intangible assets) reach very high percentage of missing values. As regard the inconsistency problem, the dataset was characterized, although to a lesser extent, by some problem of inconsistency, such as some values of *revenues* lower than zero; these two problem have been addressed together. Eliminate the observation $\mathbf{x}_i$ if a value x_{ij} is missing was a viable option, but deemed too severe; nevertheless, some inconsistencies cast doubts on the entire observation. The solution adopted was to logically divide the inconsistency in two parts: inconsistency in the *revenues* attribute caused the direct elimination of the entire observation, while other inconsistencies and all the incompletenesses were dealt in the following way:

- Through the elimination of the single inconsistent value x_{ij}, if faced;
- Through the outliers detection procedure explained later in this work;
- Leaving the incompleteness as is.

Data reduction

As just explained, the dataset downloaded was quite large, and affected, in some of its attributes, by incompleteness problems. These two factors called for a process of data reduction. The process has been done only on the attributes $\mathbf{a}_j$ (and not on the observation), and mainly manually, selecting, during the whole duration of the project, the attributes that were of more interest analysis-by-analysis.

However, before proceeding through the data reduction, an outlier detection and elimination procedure was necessary for eliminating the main inconsistencies in the database, as well as the great part of the noise.

Outlier Detection

The process of outlier detection was critical: a first exploration of the database revealed that it was clearly affected by the presence of outlier, i.e.: value that were unreasonably high or low, so much out of the range that sensibly changed the arithmetic mean of the attribute in question. Therefore, an outlier detection procedure was necessary. To do so each attribute was firstly analyzed in order to understand its distribution[5]; it was discovered that the attributes are well-described by a normal or a log-normal distribution, where the latter is a distribution in which:

$$ln(\mathbf{a}_j) \sim N[\mu_j, \sigma_j^2].; \tag{2.4}$$

[3]The list of all the attributes downloaded is available in appendix B.

[4]For more information about this notation, cfr.: Vercellis [2009].

[5]The procedure has been applied per each "group": 11 groups have been selected, therefore the procedure described for a generic attribute $\mathbf{a}_j$ has been applied eleven times, the first time to all attributes of observations belonging to the first group, the second time to all attributes of observations belonging to the second group, and so on. Details about the groups and the selection process are provided in section 4.2 at page 95

To decide which of the two best apply to an attribute, two tools has been used: the normal probability plot and the skewness index; as regard the latter, it is a measure of the asymmetry of a distribution, as stated in Carmer [1997], it is estimated as:

$$\bar{\mu}_j = \frac{1}{m}\sum_{i=1}^{m}(x_{ij} - \mu_j)^3, \tag{2.5}$$

where μ_j is the arithmetic mean of the j-th attribute. The standard error of skewness (ses), again as stated in Carmer [1997], is calculated as:

$$ses = \sqrt{\frac{6n(n-1)}{(n-2)(n+1)(n+3)}}. \tag{2.6}$$

Unfortunately, the skewness of the distribution of the attributes were almost always higher than their respective ses values, therefore much more importance has been given to the normal probability plot. The normal probability plot is a graphical technique used to asses how much a distribution resembles the normal distribution. In the chart, one axis represents the $i = 1, ..., n$ quantiles of the distribution to be assessed, while the other axis represents the same number of quantiles of the normal distribution (formally z_i), calculated through the formula (cf: Chambers et al. [1983]):

$$P(Z < z_i) = \begin{cases} 1 - 0.5^{1/n} & \text{for } i = 1 \\ 0.5^{1/n} & \text{for } i = n \\ \dfrac{i - 0.3175}{n + 0.365} & \text{otherwise} \end{cases} \tag{2.7}$$

The more the resulting function matches a straight line, the more the distribution may be considered normal. In figure 2.4, an example is shown: the normal probability plot is drawn for the attribute *liquidity.ratio*: in blue considering the attributes as is (left axis and histogram), in red considering the logarithm of the attributes (right axis and histogram); the trend is drawn as well, with its Pearson coefficient R^2, to better understand how much the two lines fit a straight line.

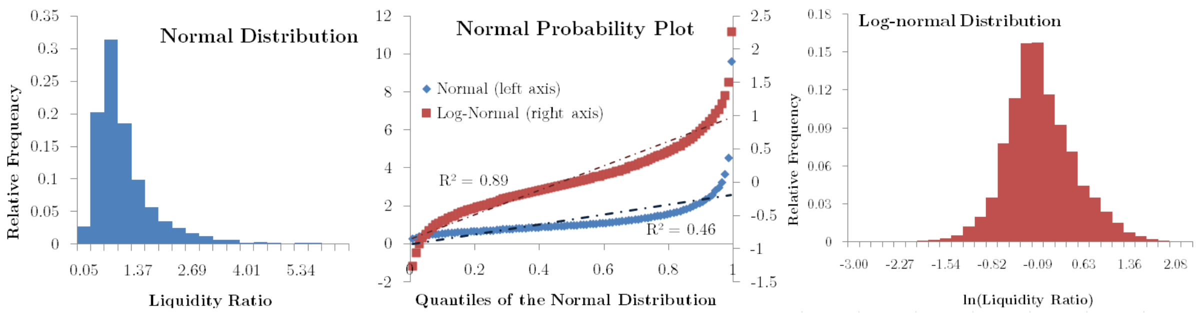


Figure 2.4: An example of histograms and normal probability plot

As can be seen from the series of chart, in this case the attribute (*liquidity.ratio*) is better fitted by the log normal distribution, confirmed also by the skewness coefficients: 2.80 for the normal distribution and 1.53 for the log-normal. In this case, the outliers procedure described in the next paragraph is applied to the logarithm of the attribute. Similar reasoning has been applied to each attribute of $\mathcal{D}$.

Knowing the distribution of the attribute, is possible to apply different outlier detection rules. As stated in Pearson [2005], Rousseeuw and Leroy [1987], there are several rules to detect outliers, among which no one is better in absolute terms; among them I selected three of the most common: 3σ, Hampel Identifier, and Box Plot rule. Given that a value x_{ij} is an outlier either if $x_{ij} > U_j$ or $x_{ij} < L_j$, the characteristics of the three rules are summarized in table 2.1.

The Hampel Identifier is generally more severe than the 3σ rule, that on the other side is less and less efficient with the increase of the number of outlier. The box plot rule is, in a perfect asymmetric distribution, less severe than the Hampel Identifier, but it can take into account the asymmetry of a distribution, avoiding possible errors of the more severe method. Summing all up, a majority criterion has been applied: whether two out of the three rules mark a value as outlier, it is removed. In this

Rule	U_j	L_j	Consider asymmetry
3σ	$\mu_j + 3 \cdot \sigma_j$	$\mu_j - 3 \cdot \sigma_j$	No
Hampel Identifier	$M(\mathbf{a}_j){+}3{\cdot}M_j[x_{ij}{-}M(\mathbf{a}_j)]^1$	$M(\mathbf{a}_j){-}3{\cdot}M_j[x_{ij}{-}M(\mathbf{a}_j)]$	No
Box Plot	$2.5a_{Uj} - 1.5a_{Lj}{}^2$	$2.5a_{Lj} - 1.5a_{Uj}$	Yes

[1] where $M(\bullet)$ denotes the median.
[2] where a_{Uj} is the upper quartile (0.75), and a_{Lj} is the lower quartile (0.25) of attribute $\mathbf{a}_j$.

Table 2.1: Outlier detection rules

way the procedure is not too much severe, and suitable for asymmetric distributions[6]. A schema of the procedure used is reported in figure 2.5.

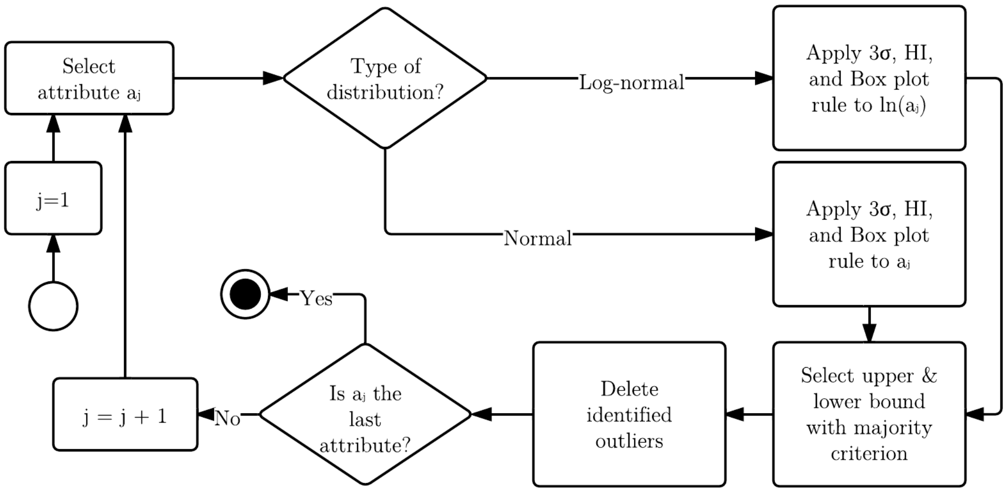


Figure 2.5: The outliers detection process

Anyhow, the procedure was to burdensome to be applied manually to all the attributes of all the eleven groups, therefore, once it was formalized, an automatic procedure has been developed through the software *MATLAB*, and has been applied to the whole database.

2.2.5 Data Exploration

The process of data exploration has been divided into univariate and multivariate exploration. As regard the former, the mean, standard deviation, median, and mode (if applicable) of each attribute in $\mathcal{D}$, grouped by ATECO code and group, as been computed.

As regard the latter, the technique called Principal Components Analysis has been applied.

Principal Components Analysis

The phase of data preparation is completed with the Principal Components Analysis, a technique that gives insights about which features of a database are more relevant, in order to reduce its size without losing valuable knowledge[7]. It was applied as a guideline for the next analyses and consideration, to understand what values drove the variance in the sample. It was applied to $\mathcal{D}$, after the outlier detection procedure. As stated in the already mentioned literature, the PCA provides n components, linear combinations of the original attributes, ordered by decreasing level of variance explained by each of them. Formally a component is written in form:

[6] Note that, given that by construction the Hampel Identifier is always more severe than the 3σ rule, the criterion is equivalent to remove a point if the Hampel identifier and/or the box plot mark it as an outlier.

[7] Smith [2002], Rencher [1992], Shlens [2005], Vercellis [2009].

$$\mathbf{c}_k = \sum_{j=1}^{n} \omega_{kj} \cdot \mathbf{a}_j = \omega_{k1} \cdot \mathbf{a}_1 + \omega_{k2} \cdot \mathbf{a}_2 + ... + \omega_{kn} \cdot \mathbf{a}_n, \tag{2.8}$$

the more the j-th coefficient of the k-th component is high (in absolute value), the more the k-th component is characterized by the j-th attribute. As stated above, the components express less and less variable, therefore the first components explain an higher percentage of the variance of the entire dataset. The bottom line is that the attributes that characterized the first components are the attributes that explain the greatest variance of the entire dataset. In table 2.2 are presented the relevant attributes of the first three components, that explain more than the 95% of the variance of the dataset:

	Revenues	OWC	Net Financial Position	Cash Flow
c1	0.97	0.11	0.08	0.21
c2	-0.10	0.94	-0.32	0.09
c3	-0.20	-0.13	-0.07	0.97

Table 2.2: First principal components ($|\omega_{kj}| > 0.1$)

As can be seen from the table, the procedure suggests four drivers with an higher possible explanatory power: *revenues, owc, net.financial.position*, and *cash.flow*; this information, as well as the other analyses carried out to explore the database, has been useful during the development of the model.

2.2.6 Model application: other relevant quantitative data sources

Although data from the Aida on-line database constitutes the base for the majority of the analyses, other data sources were used. In the end, two different sets of data have been used, which main differences are reported in figure 2.6; the two sets are:

- Groups that can be tracked back to one or more ATECO codes: the main economic data have been downloaded by the Aida on-line database based on the ATECO codes. Exportation and importation have been gathered from the Eurostat database[8];
- Groups that cannot be tracked back to an ATECO code[9]: main economic data have been downloaded by the Aida on-line database based on the list of organizations' business names, belonging to such groups, provided by Bilanci d'acciaio [2011].

All the groups but the ones called "Service centers" and "Stockists" belong to the first set.

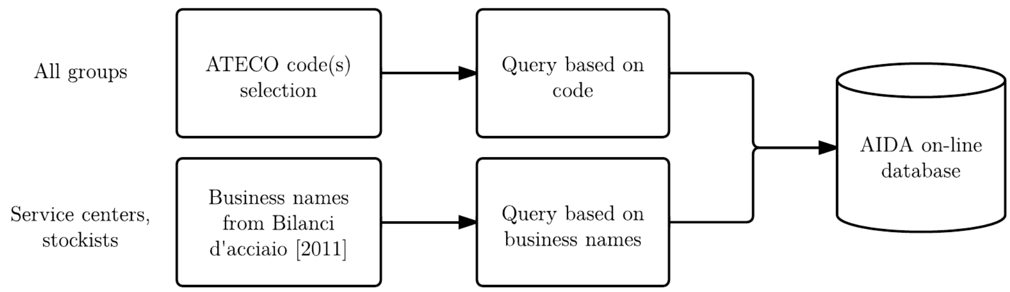


Figure 2.6: Difference in the query procedure to download data for the different groups.

However, the introduction of the second set of data highlighted an inconsistency between it and the first set, particularly evident in the analysis of common measures of organizational size. In particular, analyses of secondary sources and confrontation of the two databases highlighted that the groups "Manufacture of tubes" and "Metal casting"[10] presented higher sizes respect to what expected, especially if

[8]For more information cf.: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes.
[9]Namely: *stockists* and *service centers*, that compose the distribution tier for the tube manufacture supply chain.
[10]For a list of groups and relative ATECO code (if available), cf.: section 4.2, page 95.

confronted with the size of organizations in the "Service centers" and "Stockists" groups. To solve such inconsistency, a third set of data has been downloaded from the AIDA on-line database: the business name lists, provided by "Bilanci d'Acciaio", of the whole manufacturers within the mechanical industry in Italy[11]. Such list has been compared to the same groups identified through the ATECO codes. As can be seen also in figure 2.7, the data based on ATECO codes is affected by an excessive number of small firms respect to the data based on "Bilanci d'Acciaio". Samples check on websites cleared that most of those companies were actually mis-categorized[12]. Figure 2.8 represent graphically the inconsistency problem source. Different filters were tested to solve the issue, also based on the analysis of distribution of other size parameters; the final one actually applied was to cut off firms with revenues lower than 2.5 million €. Although this cut off surely eliminated few correctly-placed firms, it is believed that the quality of the results overall improved.

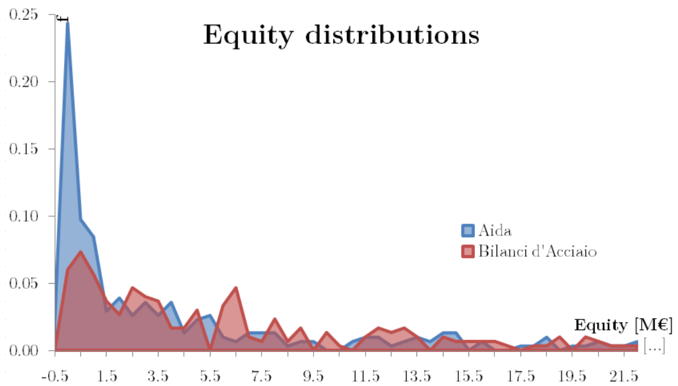


Figure 2.7: Equity distribution for data based on ATECO codes and Bilanci d'Acciaio names list.

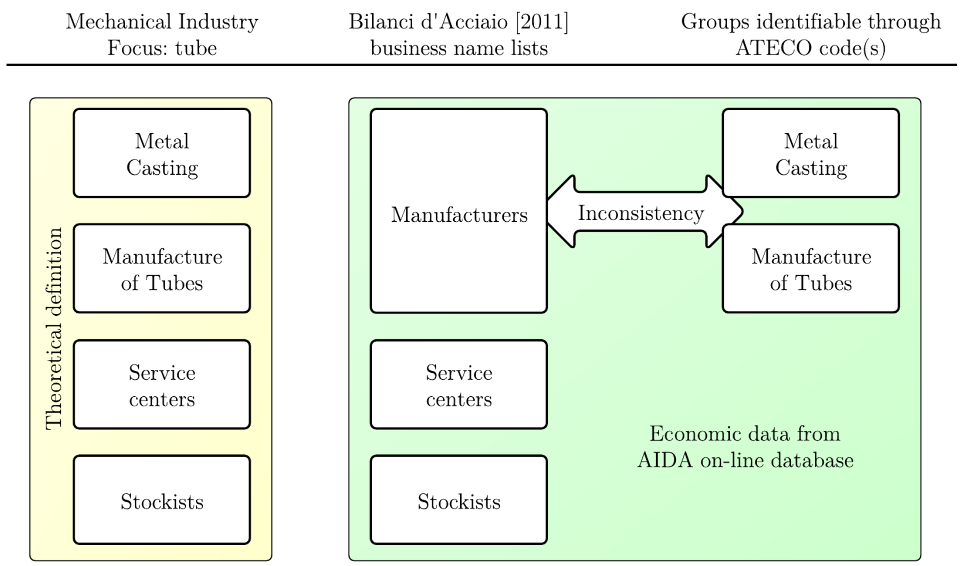


Figure 2.8: Representation of the inconsistency problem among the two main datasets.

[11]This list includes both the tube manufacturers and the metal casting groups, but do not distinguish among them; therefore, it cannot be used as reference for this work, in which such distinction is critical; however, this third list of business name provided a suitable control group for the solution of this inconsistency.

[12]As a way of example: metallurgica buzzi - website: `http://www.metallurgicabuzzi.it` - category: tube manufacturing - actual product range: home gardening metal products.

2.2.7 Model application: qualitative data

The second body of knowledge at the base of this work is composed by interviews with practitioners, domain experts from academia, and member of industry associations. The interviews have been carried out mostly by phone and in minor part in presence; the ones with practitioners (divided in two different sets) have been carried out in a structured way, the ones with the associations and experts from academia in an unstructured way. The summary of such body of knowledge is reported in table 2.3.

Set of interviews	No.	Object of the interview	Reference base group[1]
Practitioners, 1st set	10	Information on supply chain[2]	Both
Practitioners, 2nd set	8	Distribution tier structure[2]	Manufacture of tube
Professor, Politecnico di Milano	1	Supply chain structure	Machinery for food industry
Professor, Università di Brescia	1	Supply chain structure	Both
Domain experts	7	Supply chain structure	Manufacture of tube
Domain expert	1	Supply chain structure	Machinery for food industry
Domain expert	1	Distribution tier	Manufacture of tube

[1] cf. appendix A.
[2] The base groups are the two groups focus of the analysis: manufacture of tube, and manufacture of machinery for the food industry, cf.: section 4.2, page 95.

Table 2.3: Summary of the qualitative data body of knowledge

Interviews with practitioners: first set

Given the recursive nature of this work, interviews with practitioners needed to be reiterated; in particular they are divided into two groups, the first one carried out in the early phase with a general purpose, and the second one carried out later in the project, with the specific purpose of filling in blanks created in the partially-developed model.

As regards the first group of interviews, table 2.4 presents the questionnaire used as a trace; the entire body of the interviews is collected in appendix A.

No.	Question
1	No. firms in the industry
2	Average production lead time
3	Production modality
4	Seasonality
5	Purchasing markets
6	Purchasing currency
7	Sales markets
8	Sales currency
9	Percentage of raw materials on revenues
10	Percentage of direct labor on revenues
11	Other significant factors that affect COGS
12	Average invoicing period
13	Average receivables period
14	Average payable period
15	Asset growth level
16	Major needs for investments
17	Existence of particular taxation or regulation
18	Digital level of business documents exchange

Table 2.4: Questionnaire for the first set of interviews

Overall, 10 interviews have been carried out in this first phase with practitioners, from over 120 contacts. The practitioners have been selected spanning in all the range of revenue values available.

Interviews with practitioners: second set

As regards the second group, 8 interviews have been carried out, from over 40 contacts. All but one questionnaires have been fully completed. The focus of this set of interviews was on service centers and stockists, and the purpose was to have data to fill up value of arcs (initially empty) in the supply chain representation model; the questionnaire used for this second group is summarized in table A.3; the entire body of the interviews is collected as well in appendix A.

No.	Question
1	Declared category: service center or stockist
2	Importation on total purchases
3	Exportation on total purchases
4	Purchases items apart from main products[1]
5	Main cost item in income statement
6	Use of additional tier of distributors (% on value of product sold)

[1] What the firm buys apart from distributed product: raw or indirect materials, sub-components, and so on.

Table 2.5: Questionnaire for the second set of interviews

2.2.8 Model application: arc value estimation

A part of the developed model is based on a representation of a supply chain as a graph composed by node and arcs, with values on the arcs. The procedure (applied in chapter 4) to estimate a generic arc value outgoing a node i for a simple case of two consecutive nodes is reported in figure 2.9[13], and is based on the following equation[14]:

$$arc_{out}(i) = arc_{in}(i+1) + m(i+1) + inc(i+1) - [e(i) + out(i)]. \tag{2.9}$$

where:

- $arc_{out}(i)$ is the value of the arc outgoing node i, approximated as: $\sum_{j=1}^{n} Revenues_j$, where $j = 1, ..., n$ are the organization belonging to node i;
- $arc_{in}(i{+}1)$ is the value of the arc incoming node $i{+}1$, approximated as the sum of raw materials and components purchases (RmC): $\sum_{k=1}^{m} RmC_k$, where $k = 1, ..., m$ are the organizations belonging to node $i + 1$;
- $m(i + 1)$ is the value of import of node $i{+}1$, taken from the Eurostat database[15];
- $inc(i + 1)$ is the value incoming from other supply chains of node $i + 1$;
- $e(i)$ is the value of export of node i, taken from the Eurostat database[15];
- $inc(i + 1)$ is the value outgoing towards other supply chains from node i.

In the case of two consecutive nodes, two variables remain to be estimated. Formally, the previous equation (2.9) can be written as:

$$out(i) - inc(i+1) \approx \sum_{j=1}^{n} Revenues_j + m(i+1) - \left[\sum_{k=1}^{m} RmC_k + e(i)\right]; \tag{2.10}$$

[13] For more information about the components used in this figure, cf. chapter 3.

[14] The convention here is that an arc outgoing a node is referred to the node from which it starts, while an arc incoming in a node is referred to the node in which it ends.

[15] Note that for the distribution of the tube supply chain Eurostat values are not available, and those arc values have been estimated from interviews with experts and practitioners.

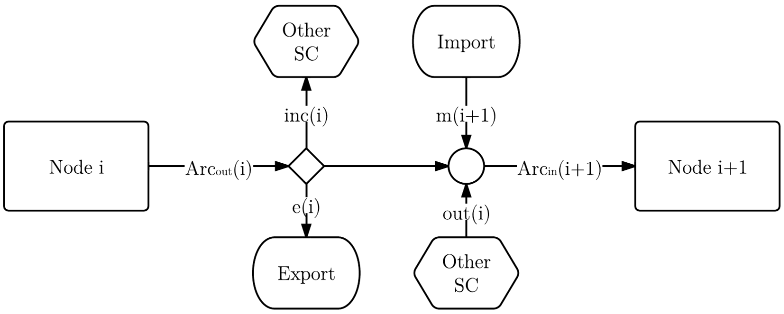


Figure 2.9: The representation of the equations system for arc estimation, in case of two consecutive nodes.

Of course, not always there are only two nodes. In case of more nodes more variables remain to be estimated, and more complicated models need to be applied. Anyway, these equation shows the type of reasoning used to estimate the arc values.

To practically estimate the values in the model application of chapter 4, two different approaches have been used.

Manufacture of tubes

As regards the manufacture of tubes, it has been possible to determine (with a sufficient level of accuracy) a number of arcs sufficient to analytically estimate the remaining, unknown, arcs. The predetermined arcs have been estimated from the quantitative data available and through information gathered from the analyses of secondary sources.

Machinery for the food industry

As regards the second supply chain analyzed, the manufacture of machinery for the food industry, the situation was more complicated. The complexity of the suppliers tier respect to the machinery for the food industry node didn't allowed an analytic estimation. Therefore, the value of the unknown arcs have been simulated and educatedly guessed based on the general understanding of the supply chain and on the analysis of secondary sources.

Chapter 3

Model

This chapter illustrates the model object of this work. Such model has been developed concurrently with its application to a part of the mechanical industry supply chain in Italy, and therefore is based on empirical evidence, as well as on the results of the literature review. The model is divided into three outputs: the first one, called *supply chain flowchart*, provides a formal graphical representation of the supply chain; the second one provides useful information about the exchanges between different supply chain nodes, while the third one, the *financial assessment of the supply chain*, assesses the financial status of the nodes, relatively to the whole supply chain; this last output can be interpreted in light of the topic of supply chain finance.
The chapter concludes with the presentation of the model prototype, a web-based prototype that presents the results of the model in a dynamic and interactive manner.

This chapter presents the model object of this work. As already discussed in the methodology, the development of such model was concurrent with its application, that is described in the next chapter; therefore, even if it is presented in such way, it is the result of multiple recursive steps and of a process of progressive generalization that was parallel with the insights and information gathered from its application.

3.1 Introduction to the model

The model takes two main inputs:

- Supply chain structure: no. of tiers, links, arc values, production processes structure, and so on;
- Economic and financial data: even if the model strictly required only a set of indicator, it is advisable to use a complete set of economic and financial data, in case further analyses are needed to complete and enhance the model's messages.

The tools used by the model are flowcharts, radar charts, line charts, a modification of Leontief's input-output economic theory, and other secondary tools. The control (i.e.: the conditions required to produce a correct output) is provided by the selection of the correct level of detail, and an understanding of the structure of the supply chain prior to the application of the model (cf.: figure 3.1).

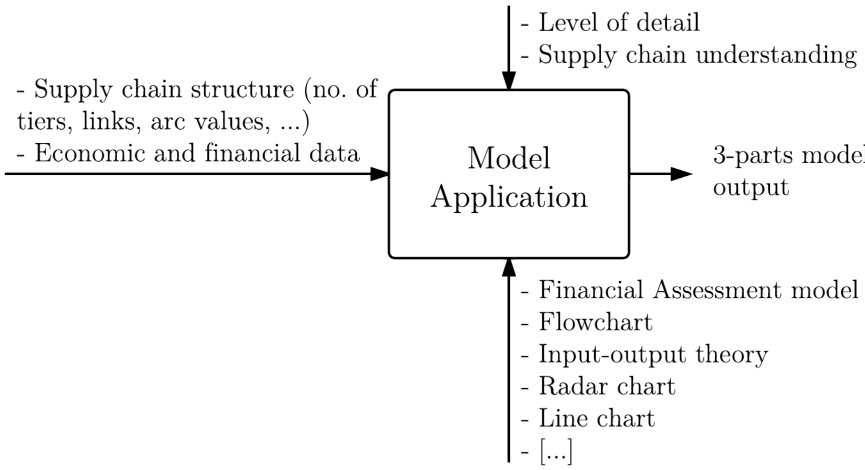


Figure 3.1: IDEF0 of the model.

The output of the model is twofold, providing a representation and a financial assessment of the supply chain under analysis. It is practically divided into three parts:

- Part 1: a flowchart representing the supply chain;
- Part 2: an node exchanges matrix that summarizes the exchanges among supply chain parties. Part 1 and 2 represent the supply chain representation;
- Part 3: the financial assessment of the supply chain; it is a tool through which is possible to assess financially the supply chain, and that is found to be linked to the evaluation of the application of non-canonical financing solutions to the supply chain.

The rest of the chapter is then organized as follows:

- The concept of supply chain used in this work is defined;
- The ontology on which the model is based is presented;
- The three parts of the model are described;
- The developed prototype is presented.

3.2 Definition of supply chain

Before entering in the detail of the model, it is useful to provide practical definition of supply chain, on which the subsequent model is based:

> A network of interconnected nodes, constituted by homogeneous groups of organizations that plan, source, process, distribute, and control raw material, components, and final products from points of origin to final customers.

This definition does not fall far from the existing ones, but, underlying the concept of network of nodes constituted by organizations, addressing the form of supply chain representation presented, for example, by Casartelli and Somaini [2004][1]. It also does not fix a number of tiers, leaving that to the definition of the points of origin, and to the identification of the final customers.

3.2.1 Motivation for a different definition

The need for a different definition of supply chain and, indirectly, for the representation methodology based on this definition, are to be found in the financial assessment methodology. Such methodology is linked to the evaluation of the application of non-canonical financing solutions to the supply chain (and in particular, of solutions of *Supply Chain Finance*). Those solutions often exploit strength and structure of links within the supply chain; consequently, in the first steps of the analyses, it is not possible to have a low, organizational-centric point of view, because that would not provide all the necessary elements to evaluate such application. Instead, take into consideration the whole supply chain can bring benefits. First of all, it allows to asses the economies of scale factor, in terms of number of organizations involved; second, SCF solutions are complex interdisciplinary instruments that needs specifics conditions within the supply chain: reaching a sufficient number of organizations, but transversally to different supply chains, risks to jeopardize the success of the SCF solution, for problem related to the physical infrastructures (e.g.: different e-invoice systems, XML schema, information systems structure, and so on), intangible infrastructures (e.g.: no relationships among industries association, objective conflicts between firms and financial institutions, or among supply chains in competition for the same pool of clients), or simply lack of proper relationships among the parties involved. Thus, it is necessary to set, at the beginning of the analyses, the level of detail on the whole supply chain, considering groups of organizations forming a supply chain of interconnected nodes. The concept just expressed is also graphically represented in figure 3.2.

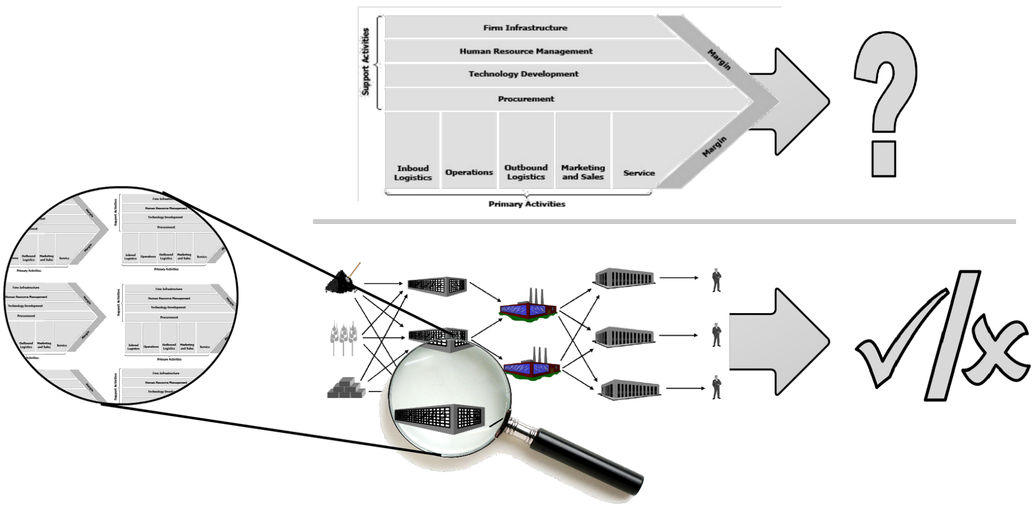


Figure 3.2: A graphical representation of the motivation for a different definition of supply chain.

Of course the evaluation of an SCF solution does not end with the analysis of the whole supply chain, but it *starts* with it. Successive analyses, at an higher, organization-centric, level of detail, are needed.

[1]Cf.: section 1.1, page 22.

3.3 Model ontology

The model ontology is fairly simple, and no particular language has been used to map it. The basic components are:

- Supply chain: is the parent-component of each other component of the ontology, and is characterized by a name[2]; to be defined it has to contain at least two nodes;
- Node: represents the basic unit of the supply chain; it is defined by a name and by a typology. The typology are divided into two groups: analyzed nodes, and unanalyzed nodes:
  - Analyzed node: are the node object of the model analyses; they are homogeneous groups of companies producing the same product, or family of product, or providing distribution services, or combination of these. There are three types of analyzed node: "supplier", "manufacturer", and "distributor":
    - "Manufacturer": is the *focus node* of the supply chain, the point of view on which the representation is built;
    - "Supplier": provides raw materials and components to the manufacturers[3];
    - "Distributor": distributes the product produced by the manufacturers; N.B.: the possible tier of distributors between the suppliers and manufacturers nodes is out of the scope of this analysis.
  - Unanalyzed node: are the node included to support the analysis of the analyzed node, but that are not analyzed on their own. This groups is composed by four types of node:
    - "Other Supply Chain"[4]: represents a generic node belonging to another, national, supply chain;
    - "Import": represents a generic node from which flows come in the object supply chain from abroad;
    - "Export": represents a generic node to which flows come out from the object supply chain to abroad locations;
    - "Customer(s)": represents a final node, end of a supply chain segment; it represents the companies to which the distributors distribute the products, and/or to which the manufacturers sell their products.
- Arc: represents the connection between two nodes; it has a value associated, and it carries a *component*, where a component can be of different kind: the only one taken into consideration in the model is the monetary one, but, for seek of completion, in this ontology also the *information*, the *unit*, and the generic components are included;
- Indicator: an indicator is an arithmetic elaboration of economic, financial, or other types of data related to the organizations composing the nodes. Indicators are divided into level 1 (used for the financial assessment model), and level 2 (used for further analyses following the main financial assessment output).
- Geographic Area: a geographic area is a location associated to a node. Given that abroad nodes are unanalyzed nodes, geographic area are only defined within the national boundaries. Being linked to an entire node, a geographic area is not an address and hardly a city; experience suggests provinces as the most suitable choice.

The entire ontology is hierarchically represented in figure 3.3

[2]Even if it is not noted, each component is always characterized by an unique ID

[3]Please note that this group includes only components and raw materials that are included in the final products, and not procurement of tangible assets (such as tools or production machinery).

[4]Shortened: Other SC, or OSC.

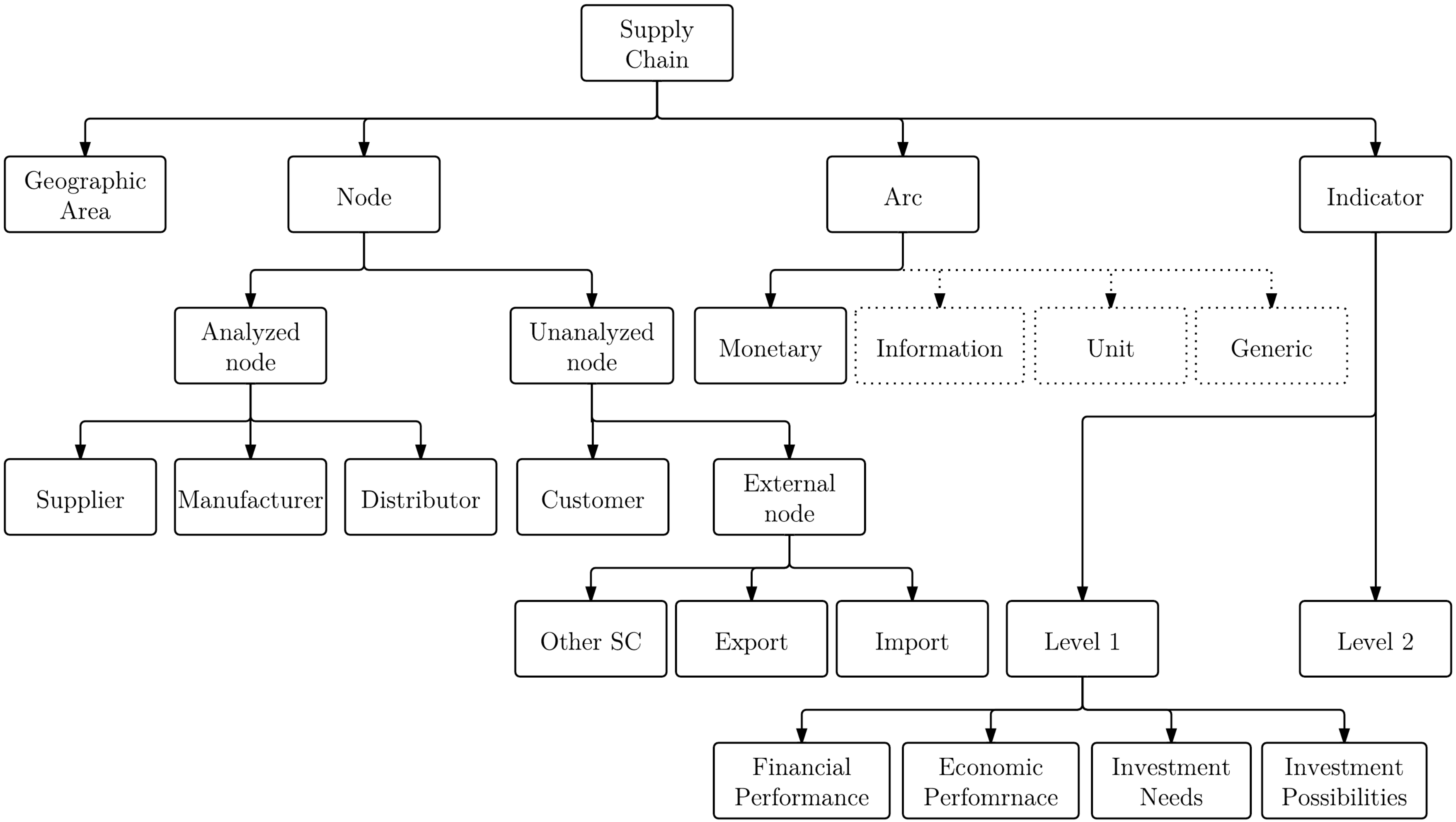


Figure 3.3: Model ontology.

3.4 Model description

As stated before, the model is composed by three parts; for each of them, the development process followed and the model application will be analyzed in the detail.

3.4.1 Part 1: Supply chain flowchart

The output of the first part of the model is called *supply chain flowchart*[5]. It takes as inputs the structure of the supply chain (specifically the number and typology of nodes, the arcs, and their monetary values), and through the application of *ad hoc* flowchart components produces the expected output; the control (i.e.: the conditions required to produce a correct output) is represented by a basic understanding of the supply chain in terms of structure and processes, the identification of the correct level of detail, the respect of the basic rules that govern any flowchart, and the preservation of readability in the chart (cf. figure: 3.4).

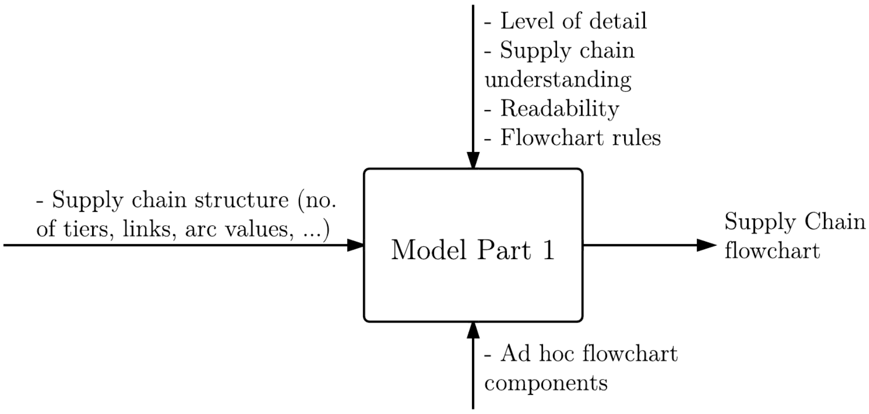


Figure 3.4: IDEF0 of model part 1.

The basic components that constitute the supply chain flowchart are represented in figure 3.5.

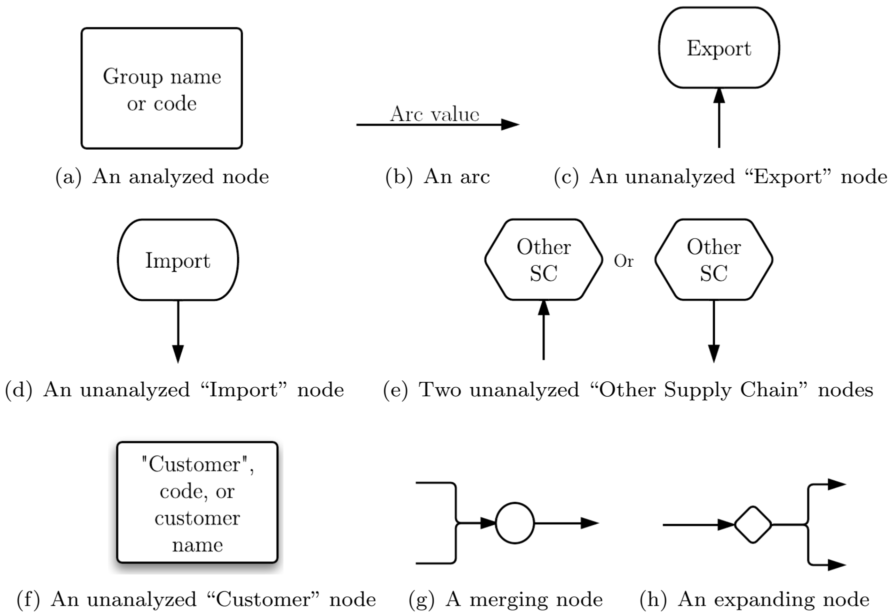


Figure 3.5: The basic components of a supply chain flowchart.

[5]For more information about flowcharts, cf.: IBM [1985], ECMA [1966].

Additionally, the flowchart is provided with four *swim lanes*, i.e.: columns that group activities in a single thread. The first three lanes encompasses the three types of analyzed node (and are called respectively: "suppliers", "manufacturers", and "distributors" lane), while the fourth contains the unanalyzed node(s) "customers".

Guidelines for the development of a Supply Chain Flowchart

With such components it is possible to build a flowchart representing the structure of the supply chain object of the analysis. Guidelines are provided to do so:

Rule 1. A supply chain is defined by at least two analyzed nodes, of which one belongs to the "manufacturers" swim lane;

Rule 2. The set of arcs entering a node (called *incoming*), and the set leaving it (called *outgoing*), must account for the 100% of, respectively, the entering and leaving value of the node. Of course different definitions of incoming and outgoing value are possible, e.g.: given a node composed by N companies, each of which in a specific time sells q units of final product(s) at price p, using for their production r units of raw materials, of unitary cost c_r, the entering value might be defined as $V_e = \sum_{i=1}^{N} r_i \cdot c_{r,i}$, and the leaving value as $V_l = \sum_{i=1}^{N} q_i \cdot p_i$, but also $V_e = \sum_{i=1}^{N} r_i$ and $V_l = \sum_{i=1}^{N} q_i$ is a viable alternative, as lots more are; point being: called $arc_{in}(k)$ the generic arc incoming node K, should hold that $V_e = \sum_{k=1}^{K} arc_{in}(k)$, and the same for the outgoing set of arcs[6]. The two obvious exception to this are the incoming node of the "Suppliers" swim lane, and the outgoing node of the "Customers" swim lane, that are neglected by default;

Rule 3. No nodes duplications are allowed: each node must be different from every other node, in terms of set of incoming and outgoing arcs for both types of nodes, and/or in terms of product, product family, or process mapped, for the analyzed nodes. Therefore:

- Corollary (a) An analyzed node can be connected at most with one of each unanalyzed node ("import", "export", "customers", one incoming and one outgoing "other SC" nodes), otherwise the unanalyzed node is not unique (cf. also the following rule);
- Corollary (b) Two analyzed nodes that are characterized by the same product, product family, or process, must be characterized by a different set of incoming or outgoing arcs, otherwise they are the same node. The vice versa holds as well[7].

A clarifying example is reported in figure 3.6.

Rule 4. Each node and its relationships with the other nodes must be uniquely identified; therefore:

- Corollary (a) For each "export" or "customer" node is allowed only one incoming arc;
- Corollary (b) For each "import" node is allowed only one outgoing arc;
- Corollary (c) For each "other SC" node is allowed only one incoming or outgoing arc (not both);
- Corollary (d) A distributor or manufacturer analyzed node connected with a "customer" node cannot be connected also to a "other SC" node[8].

Rule 5. Arcs connecting two analyzed nodes are in general allowed with the following exceptions:

- A supplier node that connects another supplier node (out of the scope of the flowchart, to be included in the "Other SC" node);

[6]Note that this implies: $\sum_{a \in A} V_l(a) = \sum_{t \geqslant A}^{T} \sum_{i \in t} \sum_{k=0}^{K_{a,i}} arc_{in}(k)$, being a a node in tier A, t a generic tier, T the number of tiers, i a generic node, and $K_{a,i}$ its set of arcs starting in node a, and similarly for $\sum_{a \in A} V_e(a)$. However, those equations would be useful in further model developments that are not taken into consideration in this work.

[7]It derives from (a) and (b) that two unanalyzed nodes cannot have the same incoming or outgoing sets of arcs.

[8]This to avoid ambiguity: a node connected to a "customer" node cannot have also a connection to an "other SC" node; wouldn't they be customers too? "Other SC" nodes have been created to identify that part of suppliers flows that goes to other supply chain, as well as that part of supply that enters the supply chain without being identified with a specific analyzed node.

- A supplier node that connects a distributor node (one of the two nodes should belong to the manufacturers swim lane, or the arc neglected and included in “Other SC”, cf. rule 6 in case of distributors sharing manufacturing characteristics);
- A manufacturer node that connects a supplier node (the supplier node should be re-positioned as manufacturer or distributor, or the arc neglected and included in “Customers” node);
- A distributor node that connects a supplier node (the supplier node should be re-positioned as manufacturer or distributor, or the arc neglected and added to “Customers”);

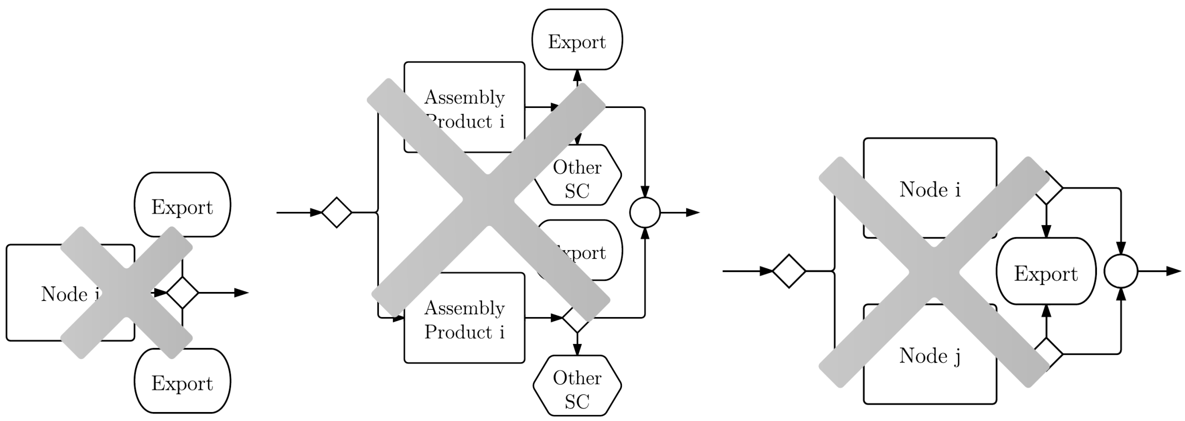
Rule 6. Arcs connecting unanalyzed nodes are not allowed;

Rule 7. A analyzed node belongs to one and only one swim lane. The only exception is an analyzed node for which there is no clear predominance between distribution ad manufacturing activities: in this case the node is positioned opportunely across the two swim lanes, and inherit the rules of both groups, with predominance of the manufacturing one in case of conflict. This exception is valid only if there is at least another manufacturer node. Additionally:

Corollary (a) “Customer” unanalyzed nodes can belong only to the customers swim lane;

Corollary (b) Every other unanalyzed node belongs by definition to the swim lane of the analyzed node to which it is connected (as stated in the corollaries of rule 4, unanalyzed node have only one incoming or one outgoing arc, so ambiguity does not exists).

Rule 8. Supplier analyzed nodes cannot be directly connected to customers node (the supplier should be replaced as manufacturer or distributor, or the arc included in “Other SC”);



(a) Corollary (a) (b) Corollary (b) (c) Corollary (b)

Figure 3.6: An example of rule 3 violation.

Putting all together, the generic link between two consecutive nodes is represented in figure 3.7. The “export” and the outgoing “other SC” nodes are conventionally said to belong the *Node i*, while the incoming “other SC” and the “import” node are conventionally said to belong to the *Node i+1*; for this reason the node of exportation is set before the importation. These two conventions arise from the practice in apply this model, and in particular from the structure of the databases used: the one used for import and export (Eurostat) is based on the NACE classification; as the reference manual states[9], the import referred to an industry code are not referred to products, but to organizations that carry out activities that create such products.

[9]cf.: Statistics on the trade of goods, user guide, Eurostat [2006]

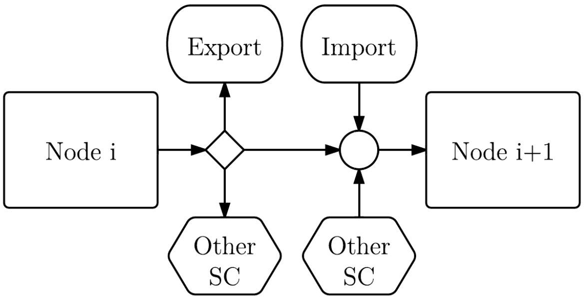


Figure 3.7: A generic representation of two consecutive nodes.

A note on the value of the arcs

It may be confusing, at this point, to understand what an *arc value* is. As explained in the ontology and in rule 2, the arcs defined in this model can have different meaning; however, the only one taken into consideration in the model application is the monetary value that passes from one node to another. Nevertheless, it is remains quite vague, on purpose: it is left to the description of each single model applications to explain what monetary value the arcs represents.

An example

An example will clarify the output produced by the first part of the model. Let's suppose to consider the national supply chain of pencil manufacturer, which figures are presented in table 3.1. Simplifying, it is formed by the suppliers of wood, the suppliers of graphite, and the manufacturers of pencils (focal point of the supply chain), that sell to a twofold tier of distributor: the point of sales (POS) like supermarkets and stationary shops, and the company that provide general office supplies; both of which have their customers (that do not overlap). The manufacturers import from abroad a part of both graphite and wood, and export a part of their production; the POS as well import and export, while the national distribution of office supplies buy and sell only on the national level. Both the suppliers of wood and graphite export and serve other supply chains.

Node	Connected with	Arc value (billion of €)
Wood Supplier	Pencil Manufacturers	4
	Export	3
	Other supply chains	26
Graphite	Pencil Manufacturers	6
	Export	2
	Other supply chains	4
Pencil Manufacturers	POS	4
	Office supplies	10
	Export	5
	Import	8
POS	Customers	5
	Import	6
	Export	4
Office suppliers	Customers	11

Table 3.1: Figures for the example supply chain.

The supply chain flowchart for this example is reported in figure 3.8.

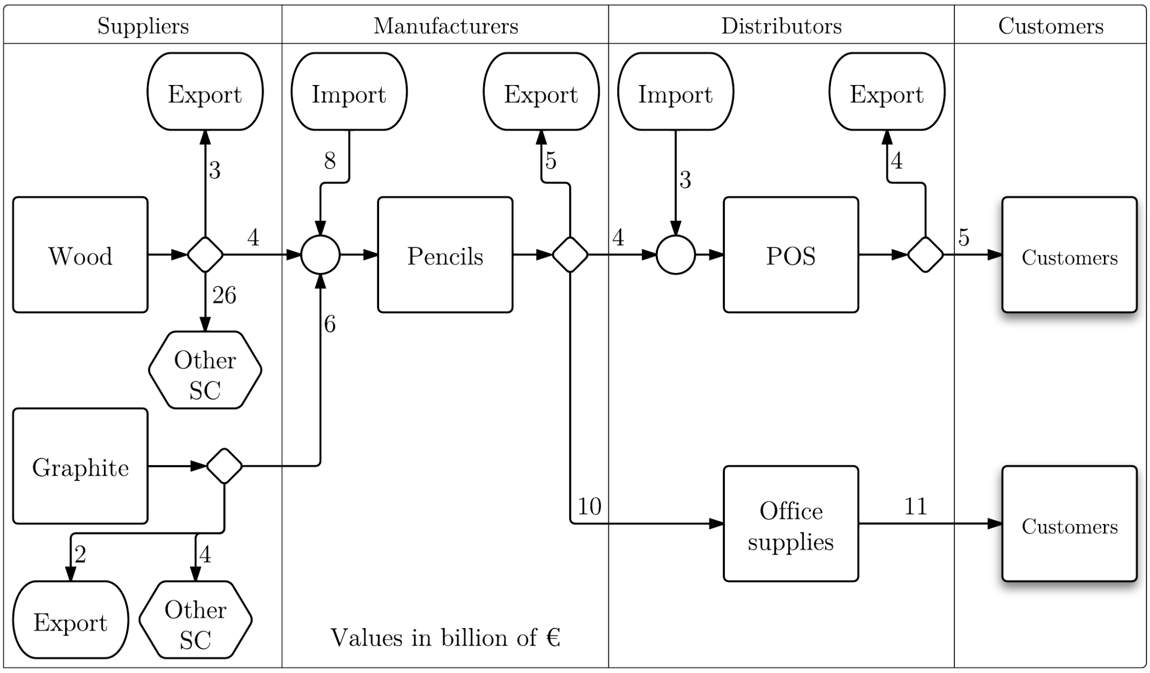


Figure 3.8: The supply chain flowchart for the example proposed.

Benefits, innovative aspects, and limitations

This graphical representation of a supply chain differs from the common methodologies, analyzed in the first chapter, for the formality through which is defined, and its orientation to the financial assessment. Although the components employed in this representation methodology are not innovative, their usage is: the definition of an ontology, together with the formality through which the guidelines for the generation of further flowcharts are provided, represents an innovative contribution for the representation methodology that rely on the definition of supply chain presented at the beginning of this section, that typically are not formalized. As will be clear in the next sections, the supply chain flowchart affects directly and indirectly the financial assessment of the supply chain: directly because a modification in the flowchart structure affects the outcome of the financial assessment, indirectly because the messages gathered from the flowchart and the matrices presented in the following section can be integrated with the financial assessment, in order to improve the quality of the overall outcome.

Limitation of this representation are mainly related to the limit to four tiers (suppliers, manufacturer, distributors, and customers), and to the limitation in the consideration of international supply chains. However, these limitations are deemed to be easily improved in future developments.

3.4.2 Part 2: the node exchanges matrix

The second model output, formed by the so-called *node exchanges matrix* and *production coefficients matrix* constitutes, together with the first one, the supply chain representation section of the model. As reported in figure 3.9, it uses as input the supply chain structure and the supply chain flowchart, as mechanism an opportune adaptation of Leontief's input-output theory[10], and as control the selection of the correct level of detail, the supply chain understanding, the readability of the results, and the practical significance of the equation system and results.

Input-output theory

Let's divide a generic supply chain in $n+1$ groups: the groups from 1 to n represent the n suppliers, manufacturers, and distributors nodes defined in the previous section, while the $(n+1)$-th group is the set of final customers' nodes. The output produced by the i-th group is x_i, the output of the i-th group

[10] For more information, cf.: Leontief [1986], Jensen [2001].

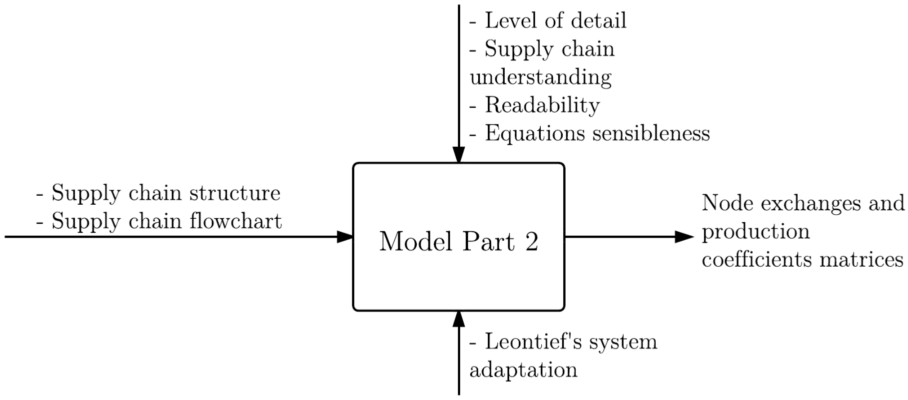


Figure 3.9: IDEF0 of model part 2.

absorbed by each intermediate sector j is x_{ij} while the output of the i-th group absorbed by the final customers (called *final demand*) is y_i; it is straightforward that, in a system closed to exchanges towards the external, the following system holds:

$$\begin{cases} (x_1 - x_{11}) - x_{12} - ... - x_{1n} = y_1 \\ ... \\ -x_{n1} - x_{n2} - ... + (x_n - x_{nn}) = y_n \end{cases} \tag{3.1}$$

A useful index can be estimated: the total output of group i absorbed by group j, per total output of j is called a_{ij}:

$$a_{ij} = \frac{x_{ij}}{x_j}. \tag{3.2}$$

Although the canonical representation of these coefficients is based on units produced, usually economic values are easier to be gathered, especially in a context such as this one; in this case, then, the index a_{ij} represents, for one euro of output of j, how many euros of output of i are needed[11] From this point onward, the meaning of a generic arc is to be intended as *economic value*. Incidentally, that means in an healthy system the following equation holds:

$$\sum_{i=1}^{N} a_{ij} = \frac{1}{x_j} \sum_{i=1}^{N} x_{ij} < 1 \ \ \forall j. \tag{3.3}$$

This is because the output produced by a group should at least be higher than the inputs it needs; simplifying the matter, one could say this equation holds because of the added value of an healthy group is higher than zero. It is straightforward to see that, in light of coefficients a_{ij}, the relationships of system 3.1 become:

$$\begin{cases} x_1 - \sum_{j=1}^{n} a_{1j} \cdot x_j = y_1 \\ ... \\ x_n - \sum_{j=1}^{n} a_{nj} \cdot x_j = y_n \end{cases} \tag{3.4}$$

Of course the whole system of equations could be viewed in matricial form: being $X = [x_j]$, $A = [a_{ij}]$, and $Y = [y_i]$, it holds that $Y = X - AX$, and $X = (I - A)^{-1}Y$; the latter represents the vector of production that allows to meet the demand of the "customers" node of the supply chain. Anyway, as regards this work, such considerations of linear algebra are quite of less interest respect to the value of matrix A itself.

[11] To be more specific: given a node output of x_j, the amount of output coming from node i that node j needs to produce its output is $x_j \cdot a_{ij}$. Thus, a_{ij} is the value of output of node i needed to produce one unit of j; note that this does not mean that if node j produces an output x_j and node i an output $a_{ij} \cdot x_j$ the system is balanced: this is true if and only if the output of i goes entirely to j, $x_{ij} = x_i$.

The analysis presented so far still does not take into consideration the whole supply chain structure presented in the supply chain flowchart. In order to do so, two modifications are needed:

- Open the system to external international exchanges: the import, m_i, and export, e_i, are introduced in the model;
- Open the system to external national exchanges: the flow of other supply chain incoming, inc_i, and outgoing, out_i, are added to the system.

The equation system 3.1 becomes therefore:

$$\begin{cases} (x_1 - x_{11}) - x_{12} - ... - x_{1n} - out_1 + inc_1 + m_1 - e_1 = y_1 \\ ... \\ -x_{n1} - x_{n2} - ... + (x_n - x_{nn}) - out_n + inc_n + m_n - e_n = y_n \end{cases} \tag{3.5}$$

Given the structure of the supply chain flowchart, it goes without saying that the value of final demand y_i is by definition equal to zero for each supplier (cf.: rule 8, section 3.4.1), as well as the value out_i is by definition equal to zero for all the nodes connected to the final customers (cf.: rule 4, corollary (d)).

Node exchanges and production coefficients matrices

The equation 3.5 can be easily seen in terms of the matrix defined above: the matrix of output, before defined X, is now vertically concatenated to the rows provided by the incoming arcs of the supply chain, and horizontally concatenated to the columns that provide the outgoing arcs of the supply chain:

$$Node\ exchanges\ matrix = \begin{bmatrix} x_{11} & ... & x_{1n} & out_1 & e_1 & y_1 & X_1 \\ ... & & & & & & \\ x_{n1} & ... & x_{nn} & out_n & e_n & y_n & X_n \\ inc_1 & ... & inc_n & & & & Inc \\ m_1 & ... & m_n & & & & M \\ x_{tot,1} & ... & x_{tot,n} & out_{tot} & e_{tot} & y_{tot} & \end{bmatrix} \tag{3.6}$$

The last column and row, added for readability purposes, represent the column[12] and row[13] totals[14]. As a consequence of what was explained in the structure of the supply chain flowchart (cf.: rule 5), all the values x_{ij} of suppliers are neglected: the corresponding columns can be removed from the node exchanges matrix, in order to facilitate readability[15]. A second matrix, called *production coefficients matrix*, can be populated with the coefficients defined by equation 3.2, for an open system; this matrix will take the form[16]:

$$Production\ coefficients\ matrix = \begin{bmatrix} a_{11} & ... & a_{1n} \\ ... & & \\ a_{n1} & ... & a_{nn} \\ a_{inc,1} & ... & a_{inc,n} \\ a_{m,1} & ... & a_{m,n} \\ a_{tot,1} & ... & a_{tot,n} \\ 1 - a_{tot,1} & ... & 1 - a_{tot,n} \end{bmatrix} \tag{3.7}$$

It is the same as matrix A defined above in this section, vertically concatenated to the coefficient a estimated for the rows that provide incoming arcs; the last rows, provided for readability purpose, represents the sum of the column $a_{tot,j} = \sum_{i=1}^{n} a_{ij} + a_{inc,1} + a_{m,1}$, and its ones' complement.

[12]With $Inc = \sum_{j=1}^{n} inc_j$ and $M = \sum_{j=1}^{n} m_j$.

[13]With $x_{tot,j} = \sum_{i=1}^{n} x_{ij} + inc_j + m_j$, $out_{tot} = \sum_{i=1}^{n} out_i$, $e_{tot} = \sum_{i=1}^{n} e_i$, and $y_{tot} = \sum_{i=1}^{n} y_i$.

[14]Note that $\sum_{i=1}^{n} X_i + Inc + M = \sum_{j=1}^{n} x_{tot,j} + out_{tot} + e_{tot} + y_{tot}$.

[15]The only row for a column corresponding to a supplier node that can have a value higher than zero is the row inc_i, that is here neglected for readability purpose (it is, however, reported in the corresponding arc of the supply chain flowchart).

[16]Of course the coefficient a_{ij} cannot be estimated for column *out*, *e*, and *y*, given that these two groups, as regard this model, do not produce any output

An example

In reference to the same example of the previous section, table 3.2 represents the node exchanges matrix for the pencil supply chain.

	Pencil	POS	Office Supplies	OtherSC	Export	Customers	Total
Wood	4	0	0	26	3	0	33
Graphite	6	0	0	4	2	0	12
Pencil	0	4	10	5	0	0	19
POS	0	0	0	4	0	5	9
Office	0	0	0	0	0	11	11
OtherSC	0	0	0				0
Import	8	3	0				11
Total	18	7	10	14	30	16	

Table 3.2: Node exchanges matrix for the example supply chain, values in billion of €.

As can be seen, each row gives the total output of each node, while each column provides the total inputs, even if this is not meaningful for every column. The production coefficients matrix for the same example is reported in table 3.3. By way of example, it is reported the estimation of some coefficients[17]:

$$a_{1,3} = \frac{x_{1,3}}{x_3} = \frac{4}{19} = 0.21; \ \ ...; \ \ a_{3,4} = \frac{x_{3,4}}{x_4} = \frac{4}{9} = 0.44; \ \ ... \tag{3.8}$$

$i \downarrow \ j \rightarrow$	Pencil	POS	Office Supplies
Wood	0.21	0.00	0.00
Graphite	0.32	0.00	0.00
Pencil	0.00	0.44	0.91
POS	0.00	0.00	0.00
Office	0.00	0.00	0.00
OtherSC	0.00	0.00	0.00
Import	0.42	0.33	0.00
Total	0.95	0.77	0.91
Ones' complement	0.05	0.23	0.09

Table 3.3: Production coefficients matrix for the example supply chain.

Model output motivation

This node exchanges matrix system provides useful insights about the structure of the supply chain, and of the relationships among players, complementary to the ones provided by the supply chain flowchart. As will be clear in the following section, understand such messages increase the benefits of the financial assessment methodology: referring to the example provided, it is clear from the node exchanges matrix that the suppliers of wood do not rely on the pencil supply chain as much as the graphite suppliers, or (as summarized in figure 3.10) that nodes “Pencil” has a distributed structure of inputs, while “POS”, and “Office Supplies” have few relations in the supply chain; these information, together with other variables, are important to understand relationships among partners, roles in the supply chain, strengths of the the links, and so on. As anticipated, they will cover a role also in the ultimate part of the model, addressing the evaluation of non-canonical financing solutions.

[17] Please note that the first two columns of the matrix are hidden, therefore the first column index is $j = 3$.

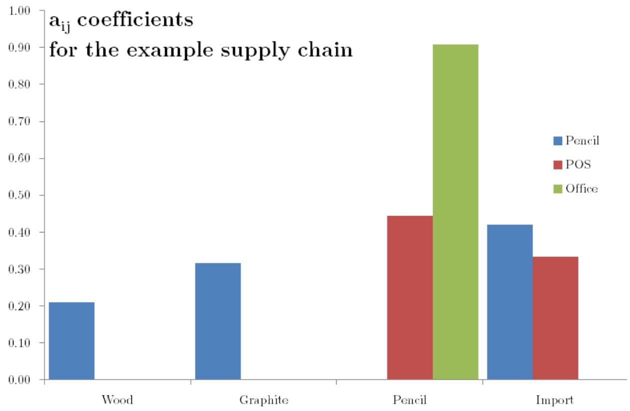


Figure 3.10: Coefficients a_{ij} for the example supply chain.

3.4.3 Part 3: the financial assessment

The third model output constitutes the "financial assessment of the supply chain" section of the model. As reported in figure 3.11, this third part uses as input the supply chain structure and the supply chain flowchart, as mechanism the radar and other types of chart, and the financial assessment model, and as control the selection of the correct level of detail, the supply chain understanding, and the readability of the results.

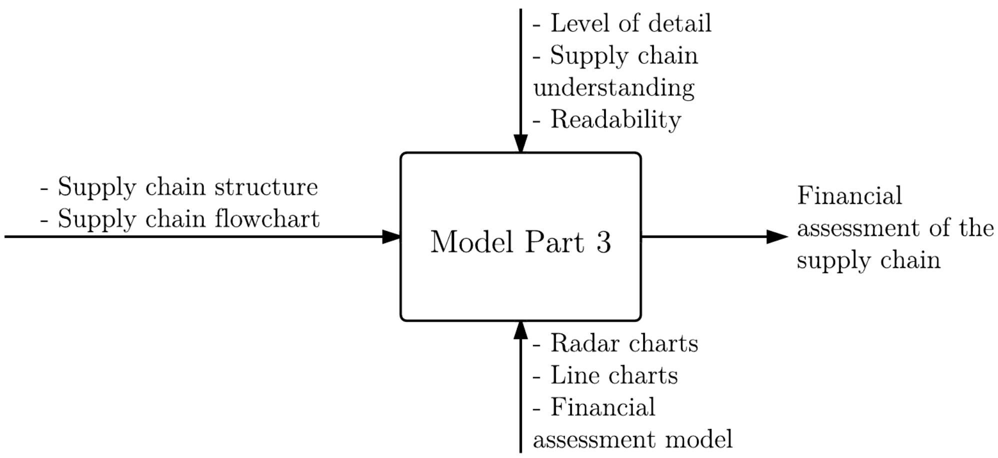


Figure 3.11: IDEF0 of model part 3.

The financial assessment of a supply chain

As stated in the literature review, the financial assessment is a concept that varies in practical application and theoretical meaning, depending on the application topic and purpose. Moreover, if this concept is translated to the less known grounds of the whole supply chain financial assessment, such variability can only increase.

In order to handle the problem efficiently, it has been divided into two smaller ones. In practical terms, the financial performance of a supply chain is considered to be expressible as a function of four parameters:

- A measure of the financial performance, in terms of cash flow management;
- A measure of the economic performance, in terms of profit generation;
- A measure of the investment possibilities, in terms of ability to increase debt through canonical financing solutions;

- A measure of the investment needs, especially in tangible assets.

This choice of parameters is not the only possible alternative: different choices, in terms of number and meaning of the parameters, are possible; this one comes from the application of the model, and its limitations are due to the practicality in which the model has been developed, but on the other side this is a strength too: such choice, even if somehow empirical, has proven to provide coherent messages during the testing phase.

As said, these four parameters, called respectively F, E, P, and N, constitute therefore the financial performance of the supply chain. Formally:

$$Financial\ Performance_{SC} = f(F, E, P, N). \tag{3.9}$$

The function f constitute the first sub-problem, and will not be explicated. What *will* be explicated is the second sub-problem, i.e.: the explicit value of the four parameters per each node. Formally (for a generic node i):

$$F_i = g_F(x_{i1}, ..., x_{in}) \tag{3.10}$$
$$E_i = g_E(x_{i1}, ..., x_{in}) \tag{3.11}$$
$$P_i = g_P(x_{i1}, ..., x_{in}) \tag{3.12}$$
$$N_i = g_N(x_{i1}, ..., x_{in}). \tag{3.13}$$

The initial problem is therefore reduced to inquire the shape of the functions g_{Par}, and of the relative variables $x_1, ..., x_n$. This process of definition of the problem and of its subproblem is also reported in figure 3.12.

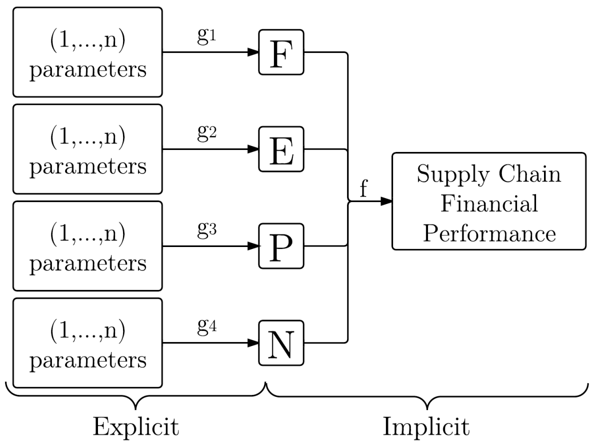


Figure 3.12: The financial assessment model theoretical definition.

Parameters estimation

To define analytically the value of the four parameters, two groups are formed (almost naturally): the first includes the parameters F and E, while the second includes the parameters P and N. For each group six measures are identified, three per measure, for a total of twelve measures, summarized in table 3.4. The group of three measures represent the set of variable $x_1, ..., x_n$, with $n = 3$, argument of the function g_{Par}. The function g_{Par} is then applied to each node of the supply chain, for each of the four parameter[18].

The motivations of the indicators of table 3.4 are clear:

[18]N.B.: another passage is required. Each of the four function g_{Par} has only three arguments, but the nodes contain groups of organization. An aggregator is needed, i.e.: a function that translate the same measures of each organization in the single value argument of the function. The simplest aggregator (used in the model application, cf.: chapter 4) is the arithmetic mean, but different aggregator, such as the median or more complex function are valid as well.

Group	Parameter	Measure	Metric
Financial-Economic	F	Days of receivable[1]	$DOR = \frac{Accounts\ Receivable}{Revenues} \cdot 365$
		Days of payable	$DOP = \frac{Accounts\ Payables}{Raw\ Material\ Purchased} \cdot 365$
		Days of inventories	$DOI = \frac{Total\ inventories - Advanced}{COGS} \cdot 365$
	E	EBIT	
		EBITDA	
		ROS	$ROS = \frac{EBIT}{Revenues}$
Investment needs-possibilities	P	Leverage	$Leverage = \frac{Debt}{Equity}$
		Financial Charges on EBITDA	$FConEBITDA = \frac{Financial\ Charges}{EBITDA}$
		Net Financial Position[2]	$NFP = DBL - Liquid\ funds$
	N	Δ(Tangible Assets)	$\Delta TangA = \frac{TangA_t - TangA_{t-1}}{TangA_{t-1}}$
		DA on Total Assets[3]	$DAonTA = \frac{DA}{Total\ Assets}$
		Asset Turnover	$AT = \frac{EBIT}{TotalAssets}$

[1] As way of example, for a node of N firms, this indicator is: $DOR = \frac{365}{N} \cdot \sum_{i=1}^{N} \frac{Accounts\ Receivable_i}{Revenues_i}$.
[2] Where DBL=Debts versus banks and other lenders.
[3] Where DA stands for Depreciation and Amortization.

Table 3.4: Measures used for each parameter of the model part 3.

- F: they represent the ability of a node of managing the cash flow. Being EBIT equal, the ability of generating cash flow depends on those measures;
- E: they represent the ability of a node of producing profit, in gross terms (EBITDA), curtailed of depreciation and amortization (EBIT), and in relative terms (ROS);
- P: they represent the possibility of a company of increase its debt through canonical financing solutions. If the ratio of debt and equity is too high, if the financial charges are too much elevated respect to the EBITDA, or if the Net Financial Position is too high, the company won't be able to increase its debt through canonical means;
- N: they represent capital necessities, due to investment needs. If the tangible assets increased from the previous year, the value of depreciation and amortization is high respect to the total asset value, and the assets turnover is low, it is likely that a node needs more capital to renew its assets.

Once each measure is estimated per each node, the first intermediate output of this part of the model can be developed. It is composed by a couple of radar charts, divided horizontally in two parts: the upper half of the first radar represents the parameter F, while the bottom half represents parameter E;

the upper half of the second represents parameter P, while the lower half represents parameter N. An example of such couple of radars is presented in figure 3.13.

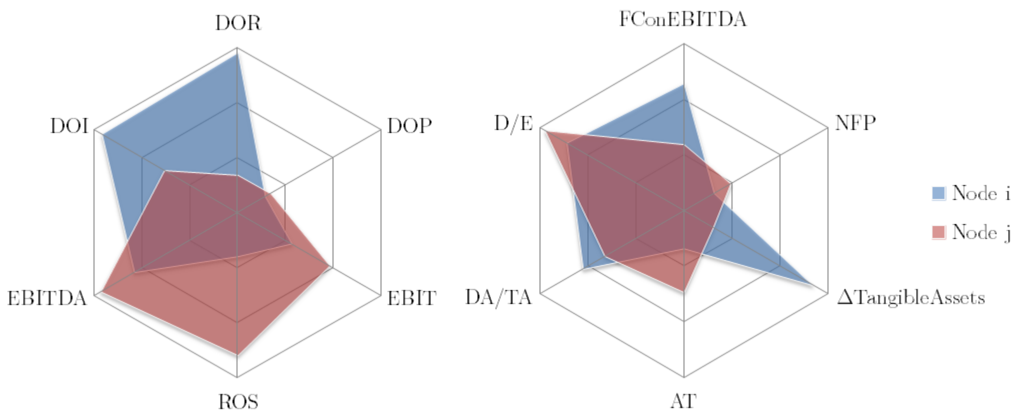


Figure 3.13: Example of radars charts, output of model part 3.

The calculation of each value of the radar is rather simple: it is a normalization of the values of the corresponding measure in the interval [0;1]. For a group of $i = 1...N$ nodes, the value of the k-th measure to be plotted on the corresponding radar axis is[19]:

$$x_{i,k,radar} = \frac{x_{i,k} - x_{m,k}}{x_{M,k} - x_{m,k}}; \tag{3.14}$$

where:

- $x_{i,k,radar}$ is the radar-axis value for node i, indicator k;
- $x_{i,k}$ is the measure value (e.g.: the arithmetic mean of the indicator for firms belonging to node i), for node i, indicator k;
- $x_{m,k}$ is the minimum value for indicator k, $x_{m,k} = \min_i x_{i,k}$;
- $x_{M,k}$ is the maximum value for indicator k, $x_{M,k} = \max_i x_{i,k}$.

Figures of merit

The shape of the function g_{Par} is constituted by a *figure of merit* applied to the radar charts. The calculation method is the same for all four parameters, a weighted average of the three measures of each parameter, for each node; for example, g_F for node i is the weighted average of $DOI_{i,k,radar}$, $DOR_{i,k,radar}$, and $DOP_{i,k,radar}$. The weights are needed to provide sense to the mean itself; in fact, taking into consideration again parameter F, not all the three measures that constitute it produce the same effect as they increase: an increase in DOI or DOR is detrimental for the meaning assign to F (the ability of managing cash flow), while an increase in DOP is desirable (all other things being equal); to correct the mean taking into consideration such effects, a multiplicative weight (a sort of *dummy variable*), called d_k, is included. It assumes values (+1) or (-1), respectively, if an increase in the k-th measure make better or worse off the respective parameter: therefore, DOR and DOI will have $d_k = -1$, because if they increase, the node under analysis is worse off in the management of cash flow, while DOI will have $d_k = +1$, because if it increases, the node is better off in the management of cash flow. The complete set of the variable d_k are reported in table 3.5.

Finally, the function g_{Par} can be written as[20]:

[19]Although it is subjective, a different and somehow more common form of normalization may be considered preferable:

$$x_{i,k,radar} = \frac{x_{i,k}}{\sum_{j=1}^{N} x_{j,k}},$$

however, this form is not suitable in case of $x_{i,k} < 0$, thus, it cannot be always applied in this context.

[20]Where, synthetically, $\mathbf{x}_i = (x_{i1}, x_{i2}, x_{i3})$ represents the vector of three measures belonging to parameter Par (i.e.: listed in the proper row in table 3.4 at page 80.

Measure k	Dummy variable d_k
DOR	-1
DOP	+1
DOI	-1
EBIT	+1
EBITDA	+1
ROS	+1
FC on EBITDA	-1
Net Financial Position	-1
Leverage	-1
Δ(Tangible Assets)	+1
DA on Total Assets	+1
Asset Turnover	-1

Table 3.5: Dummy variables used in the model.

$$g_{Par}(\mathbf{x}_i) = \frac{\sum_{k \in Par}(2 \cdot x_{i,k,radar} - 1) \cdot d_k}{3}, \ \forall i. \tag{3.15}$$

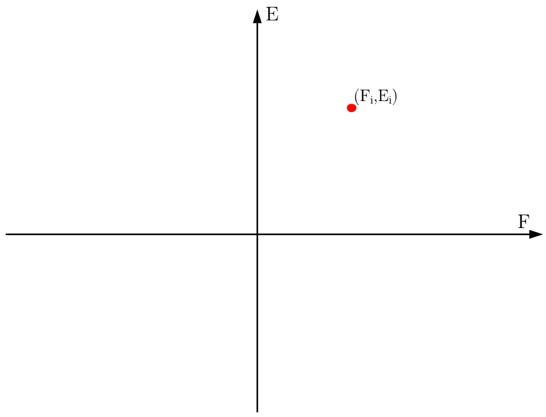
Such function spans in the interval [-1,1], with -1 being the worst situation possible (in relation to the other nodes), and 1 the best one. For example, if a node scores three "0"s in all the three measures of a parameter "P", and these measures are all "detrimental" for P, the figure of merit is:

$$g_P(\mathbf{x_i}) = \frac{(2 \cdot 0 - 1) \cdot (-1) + (2 \cdot 0 - 1) \cdot (-1) + (2 \cdot 0 - 1) \cdot (-1)}{3} = 1. \tag{3.16}$$

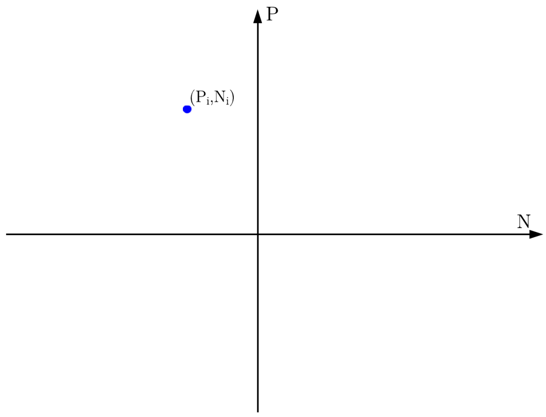
This situation would be, in fact, the best possible.

Financial assessment scatter plots

Summarizing, so far four figures of merit have been produced, each of which represents one of the four parameters: financial (F), economic (E), investment needs (N), and investment possibilities (P). These four parameters in turn are clustered into two groups: the economic with the financial and the investment needs with the investment possibilities. The next step is to create two scatter plots, one for each group. Two generic scatter plots, for a node i, are presented in figure 3.14. Although not explicated, the axes span both between -1 and +1, and cross at (0;0).



(a) Financial-Economic group



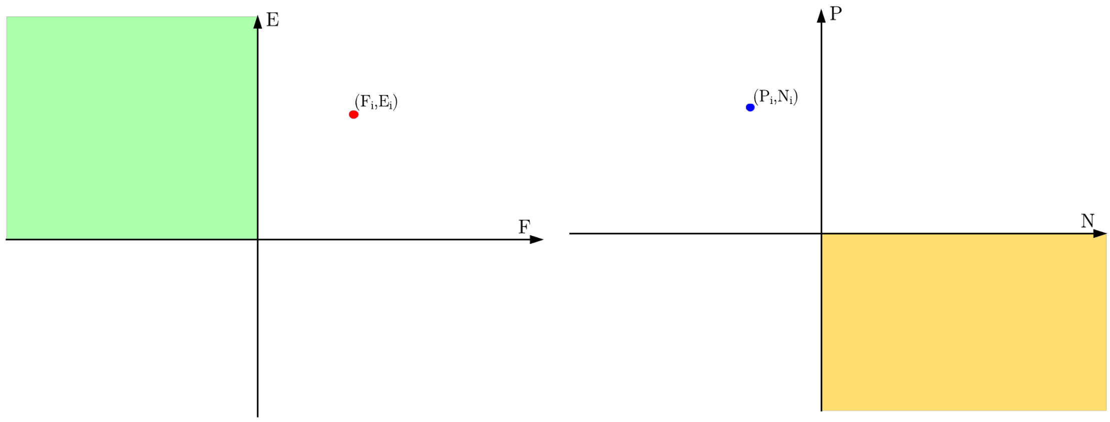
(b) Investments Needs-possibilities group

Figure 3.14: Example of scatter plots.

Each scatter plot identifies four areas, corresponding to the four quadrants. They are:

- Financial-Economic group (from the 1st quadrant, clockwise):
  - High F, high E: the node presents an high Financial and high Economic performance respect to the other nodes;
  - High F, low E: the node presents an high Financial performance (i.e.: an high performance in managing the receivable and payables respect to the other nodes), but a weak performance in the generation of profit;
  - Low F, low E: the node presents an weak performance as regards both the parameters: it is weak in generating profit and in effectively managing cash flows;
  - Low F, High E: the node presents a good performance in generating profit, but a weak performance in managing cash flows. This quadrant represents a zone of interest, for this reason, it is colored (pale green).
- Investments needs and possibilities:
  - High N, high P: the node presents strong investment needs, but also strong possibilities of increase debt through canonical means;
  - High N, low P: the node presents strong investment needs, but, respect to the other nodes, it is less able to face those needs through canonical means to increase debt. This quadrant is of interest, and therefore it is colored (pale orange);
  - Low N, low P: the node presents weak investment needs, as well as weak possibilities of reach new debt through canonical means;
  - Low N, high P: the node presents few needs for new capital, and strong possibilities of increase the existent debt through canonical means.

The matrices (scatter plots) with the highlighted zones of interest are presented in figure 3.15.



(a) Financial-Economic group

(b) Investments Needs-possibilities group

Figure 3.15: Example of scatter plots with highlighted zone of interest.

Evaluation of non-canonical financing solutions

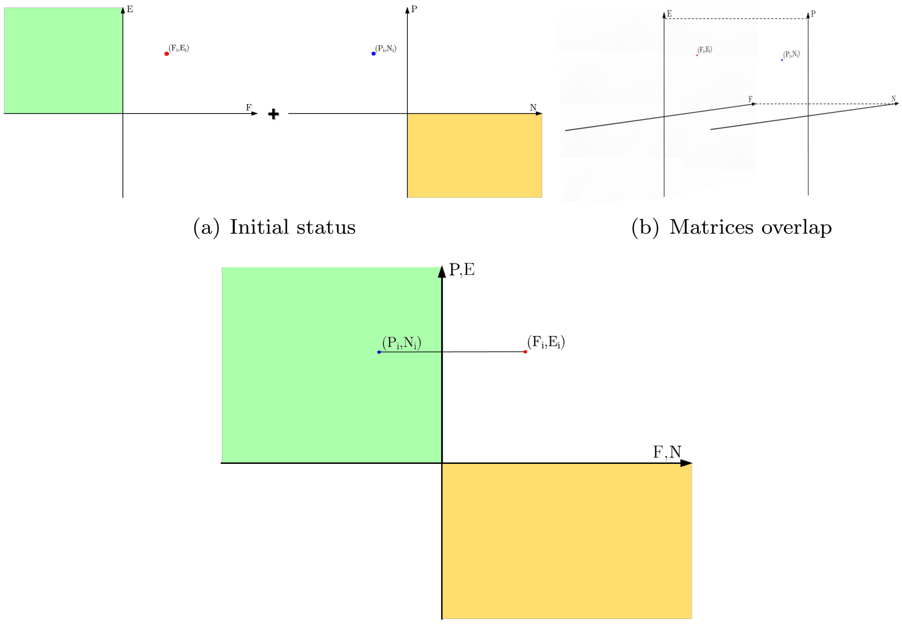
It is in highlighting the the so-called zones of interest that the first link among the financial assessment and non-canonical financing solution appears. Focusing on the subset of such solutions called *Supply Chain Finance*, it is possible to identify two sets:

Set 1. Composed by solutions apt at optimize the organizations' cash flow management, in order to optimize their cash-to-cash cycle;

Set 2. Composed by solutions apt at provide alternative, competitive, means of financing to organizations in a supply chain exploiting the strength of supply chain relations, in order to directly optimize their *WACC*.

Thus, it is straightforward that a company that has a weak performance in terms of management of the CCC (cash to cash cycle), but a good performance in terms of profit generation, is a good candidate for the first set of solution, while one that has strong investment needs, but weak capacity of increase such debt through canonical financing solutions, is likely to be a good candidate for solutions in the second set. On the same line of reasoning, a supply chain node characterized by a low value of F and high value of E, is likely (if the aggregator chosen makes sense) to contain organizations that can benefit from SCF solution in the first set, while a node with an high value of N and a low value of P is likely to contain organizations that can benefit from SCF solutions within the second set. A careful reader ought to note that this view is in line with the what expressed in section 3.2.1.

What *does the trick*, is that the two scatter plots can be overlapped, in order to concentrate all the results of the model in a single chart. Once the scatter plots are overlapped, the two points, that correspond to the same node, are connected by a line, creating a segment. The process is graphically represented in figure 3.16.



(a) Initial status (b) Matrices overlap

(c) Segment creation

Figure 3.16: The matrices overlap process.

As can be easily understood, considering the quadrants, there are $4 \cdot 4 = 16$ typologies of segments[21]. Such 16 combinations are grouped into 9 clusters, based on the similarity in the message provided. The combinations with the assigned cluster are reported in table 3.6.

The nine identified clusters are:

Cluster 1. High performer: the node has relatively high values in all the four parameters; such high performance is not easily referable to an SCF framework, but it bestows importance to the node within the supply chain: it should not be neglected in the analysis for the application of an SCF solution.

Cluster 2. Cash provider: the node is still an high performer, and it may assume the role of cash provider, i.e.: organization within this node may provide capital to other member of the supply chain, for mutual benefit[22];

Cluster 3. Alternative means of financing: the node presents a good performance in the Financial-Economic parameters, but it has strong investment needs and low investment possibilities. It is a good candidate for SCF solutions that provide alternative means of financing to players in the supply chain;

[21] N.B.: the segment are oriented: the segment $(P_i = 0.5, N_i = 0.5), (F_i = -0.5, E_i = -0.5)$ is different from the one $(F_i = 0.5, E_i = 0.5), (P_i = -0.5, N_i = -0.5)$.

[22] SCF solutions set 2, cf.: page 83.

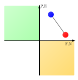
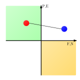
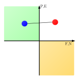
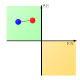
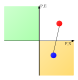
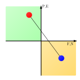
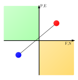
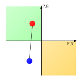
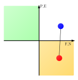
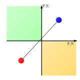
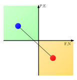
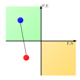
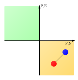
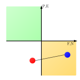
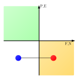
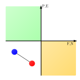
ID	Schema	Parameter F	E	P	N	Cluster		ID	Schema	Parameter F	E	P	N	Cluster	
1		H	H	H	H	1	High performer	9		L	H	H	H	7	Cash flow opt.
2		H	H	H	L	2	Cash provider	10		L	H	H	L	7	Cash flow opt.
3		H	H	L	H	3	Alternative means of financing	11		L	H	L	H	8	SCF needy
4		H	H	L	L	4	Doubtful case	12		L	H	L	L	7	Cash flow opt.
5		H	L	H	H	5	Low performer	13		L	L	H	H	4	Doubtful case
6		H	L	H	L	9	Potential cash provider	14		L	L	H	L	9	Potential cash provider
7		H	L	L	H	6	Possible AMF	15		L	L	L	H	5	Low performer
8		H	L	L	L	5	Low performer	16		L	L	L	L	5	Low performer

Table 3.6: Cluster identification.

Cluster 4. Doubtful case: it is not possible to draw conclusions on this node; its performance may be improved through SCF actions, or it can, under the right circumstances, play an active role in an non-canonical financing framework, or its performance may not be affected by such solutions. Further investigation, e.g.: on the structure and the relationships within players in the supply chain, are necessary;

Cluster 5. Low performer: the node has an overall, relative, bad performance, in terms of profit generation, cash flows management, debt structure, or a combination of those. This means only that this analysis marks nodes in this cluster as less suitable for non-canonical financing solutions, not that such solutions should be excluded *a priori*; as already mentioned, further inquires are always needed;

Cluster 6. Possible alternative means of financing: the node presents characteristics similar to cluster 3 as regards the investment needs-possibilities, but its poor profit generation performance casts doubts on the efficiency of set 2 SCF solutions. Nevertheless, this weak performance may be due to a lack of capital: in this case the upper-mentioned solutions are likely to better off organizations in this node;

Cluster 7. Cash flow optimization: the node presents, on average, a good performance in profit generation, but a weak one in management of cash flows. It is likely that, in a supply chain, organizations within this node will need non-canonical financing solutions apt to optimize the CCC[23];

Cluster 8. SCF needy: nodes in this cluster presents both the need for CCC optimization and for alternative means of financing;

Cluster 9. Potential cash provider: the node presents characteristics of a cash provider, but with a relative weak performance in profit generation. The reason of such performance should be inquired, and the possibility of associate nodes in this cluster to nodes in cluster 2 should be kept in mind, even if nodes in cluster 2 are, in general terms, more suitable for the role of cash provider.

The logical expressions of equivalence for each cluster are reported in table 3.7; they have been especially useful in the development of the prototype[24]. A parameters is *TRUE* if higher than 0, *FALSE* if lower.

[23] SCF solutions set 1, cf.: page 83.
[24] Cf.: section 3.5, page 88.

Cluster		Logic expression[1]
1	High performer	$F \wedge E \wedge P \wedge N$
2	Cash provider	$F \wedge E \wedge P \wedge \neg N$
3	AMF	$F \wedge E \wedge \neg P \wedge N$
4	Doubtful case	$(F \wedge E \wedge \neg P \wedge \neg N) \vee (\neg F \wedge \neg E \wedge P \wedge N)$
5	Low performer	$\neg E \wedge (\neg F \vee \neg N \vee P) \wedge (F \wedge N \vee \neg P)$
6	Possible AMF	$\neg E \wedge F \wedge \neg P \wedge N$
7	CFO	$E \wedge \neg F \wedge (P \vee \neg N)$
8	SCF needy	$\neg F \wedge E \wedge \neg P \wedge N$
9	Potential cash provider	$\neg E \wedge P \wedge \neg N$

[1] Convention: AND $\rightarrow \wedge$, OR $\rightarrow \vee$, negation $\rightarrow \neg$.

Table 3.7: Logic expressions for each cluster.

Summing up, after the radar chart are developed, two scatter plots are developed, representing the four parameters. All the analyzed nodes of the supply chain are mapped in the scatter plots, for a total of two points per node: a point of coordinates (F_i, E_i), and the other of coordinates (P_i, N_i). Thus, the scatter plots are overlapped, and the point joined, creating a segment. Considering each quadrant of the two matrices, $4 \cdot 4 = 16$ unique segment are possible: the combinations that give similar information about the node are clustered together, producing nine clusters altogether.

An example

This third output of the model is applied in this section to the example already presented before, the pencil supply chain. The arithmetic means of the firms constituting the nodes are reported in table 3.8. From those values, the values $x_{i,k,radar}$ are developed: as a way of example, the value of the radar axis "EBIT" for the node "Pencil" is reported:

$$x_{Pencil,EBIT,radar} = \frac{3-1}{4-1} = 0.67. \tag{3.17}$$

	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
Wood	86	36	24	4	5	0.13	0.02	0.98	8	0.2	0.18	0.96
Graphite	26	38	42	1	2	0.08	0.08	1.8	6	0.4	0.14	1.04
Pencil	13	49	24	3	6	0.16	0.12	2.4	5	0.3	0.12	1.08
POS	14	0	62	2	5	0.22	0.26	2.1	4	0.1	0.08	1.22
Office	46	69	36	4	7	0.36	0.03	1.4	14	0.1	0.06	1.18

Table 3.8: Arithmetic means for radar creation.

The values used for plotting the radar are reported in table 3.9. The radars themselves are reported in figure 3.17.

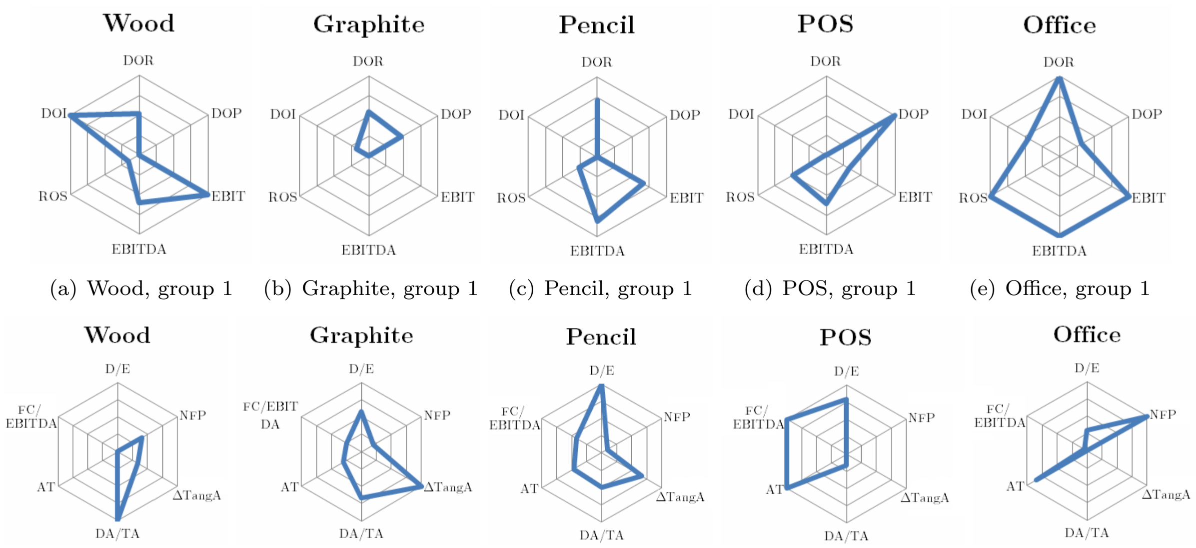
From the radar charts, applying the transformation showed in equation 3.15, page 82, is possible to derive the segment coordinates per each node. The points (F_i, E_i) and $P_i, N_i)$ are summarized in table 3.10; as a way of example, the point $g_N(x_{Pencil})$ is estimated as:

$$g_N(x_{Pencil}) = \frac{(2 \cdot 0.67 - 1) \cdot (-1) + (2 \cdot 0.50 - 1) \cdot (1) + (2 \cdot 0.46 - 1) \cdot (1)}{3} = -0.14. \tag{3.18}$$

The final scatter plot, containing all the segment of each node of the example supply chain, is reported in figure 3.18.

	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
Wood	1	0.52	0	1	0.6	0.16	0	0	0.4	0.33	1	0
Graphite	0.18	0.55	0.47	0	0	0	0.25	0.58	0.2	1	0.67	0.31
Pencil	0	0.71	0	0.67	0.8	0.27	0.42	1	0.1	0.67	0.5	0.46
POS	0.01	0	1	0.33	0.6	0.5	1	0.79	0	0	0.17	1
Office	0.45	1	0.32	1	1	1	0.04	0.3	1	0	0	0.85

Table 3.9: Values used to plot the radars.



(a) Wood, group 1 (b) Graphite, group 1 (c) Pencil, group 1 (d) POS, group 1 (e) Office, group 1

(f) Wood, group 2 (g) Graphite, group 2 (h) Pencil, group 2 (i) POS, group 2 (j) Office, group 2

Figure 3.17: Radar charts for the example supply chain.

	F	*E*	*P*	*N*
Wood	0.65	0.18	0.73	0.11
Graphite	-0.23	-1	0.32	-0.35
Pencil	-0.14	0.16	-0.01	-0.14
POS	-0.32	-0.05	-0.19	0.44
Office	-0.24	1	0.11	0.23

Table 3.10: Values used to plot the matrix for the example supply chain.

The knowledge communicated by the tool is weakened by the fact that this is only an example; however, in order to provide insights on the purpose for which this tool is provided, an example of conclusion is drawn from the matrix: as is possible to see in table 3.11, the node “Office” and “Pencil” are in the cluster ”cash flow optimization”; given that among these two nodes there is a direct arc, the hypothesis of starting an SCF program for reducing the receivable (for the “Pencil”), and increase the payable (for the “Office”) involving on a large scale companies belonging to these two nodes should be inquired.

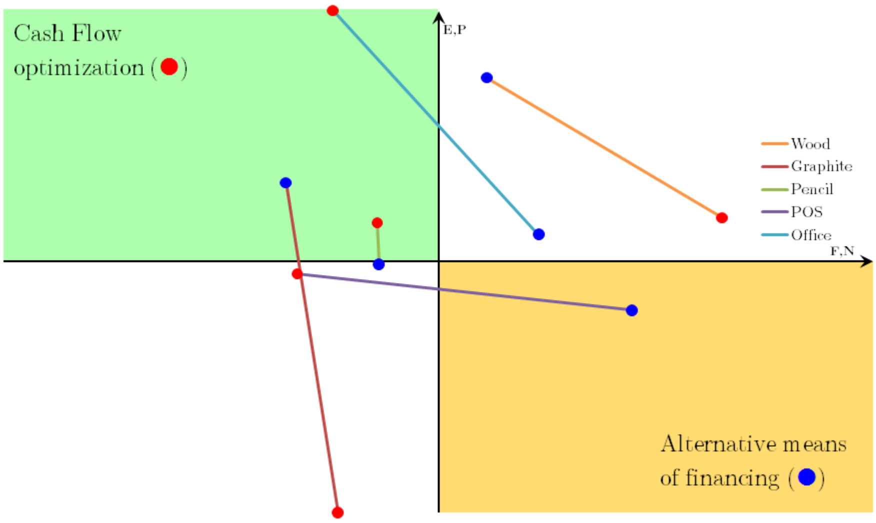


Figure 3.18: The final scatter plot for the example supply chain.

Node		Cluster
Wood	1	High performer
Graphite	9	Cash provider
Pencil	7	Cash flow optimization
POS	5	Low performer
Office	7	Cash flow optimization

Table 3.11: Values of the four parameters for the example supply chain.

Considerations on the financial assessment

As already stated, this model does not have the purpose of provide a comprehensive and *standalone* analysis tool for the evaluation of the possible application of SCF solutions to a supply chain. Such evaluation is a complex process that requires various analyses, at a different level, with different purposes, and different techniques. This model is thought to be set at the beginning of such process, when it is deemed paramount to carry out an analysis at the supply chain-level; effective SCF solutions often need specific conditions in the whole supply chain (e.g.: the presence of strong links among two partners, or existence of a node with specific characteristics); such conditions, to be assessed, require analyses that take into consideration the whole supply chain. This model, through its characteristic of relativity respect to the entire supply chain, is suitable for assessing one or more of those conditions: for example, the model do not select the best *cash provider* in the market, but select the best one *within the specific supply chain*, because it is within the supply chain that, likely, the application of an SCF solution will bring benefits. Nevertheless, further analyses are still required, at more detailed levels, organization-by-organization. It is through the entire set of such analyses that is possible to correctly evaluate the application of an SCF solution.

3.5 Model prototype

The description of the model is completed with the description of the prototype, presented in this section. It has been built to provide insights about the desired usage of the model that were difficult to be provided in written form.

The prototype is currently available at the url: `http://supplychain.altervista.org`; it, basically, produces the three outputs of the model, based on inputs inserted by the user through specific forms. The prototype dynamically presents the outputs based on the user's requirements, and allow (although limited) modifications of the output representation to fit user's needs.

3.5.1 Purpose of the prototype

The purpose of this prototype is to disclose potentialities of the model that cannot be carried out through a written document. In particular, such potentialities are related to the interactivity of the model with the user and the personalization of the output; concepts that are easily showed through a dynamic prototype. The concepts just mentioned represent the *instrumental* nature of the model that, although its conceptual nature, gives it some characteristics of a *tool*. In fact the model does not provide answers itself, but aids in accomplish tasks, e.g.: the financial assessment of the evaluation of SCF solutions, that, by all means, requires more than maths and flowcharts to be efficiently carried out. The supply chain understanding, the sensibility of the user, and a firm-level series of analyses are paramount to fully accomplish such tasks. Therefore, it's unreasonable to try to develop an answer-machine to the question "is it ok to implement a SCF solution in this supply chain?", but instead, it is reasonable to develop a *tool* that *practically* helps users to carry out the necessary analyses (or part of them) to answer such question. To state this out clearly, and to shape the model in a form that best suits its foreseen purpose, this prototype has been developed.

3.5.2 Limitations

The prototype is not a final, comprehensive representation of the model, and, given its demonstrative purpose, has limitations in its functionalities. Such limitations are:

- Only closed-system SC are allowed: no import/export or exchanges with other supply chains;
- One single customer node is allowed;
- Only three typology of arcs are allowed: from a supplier to a manufacturer, from a manufacturer to a distributor, from a distributor to the customers;
- Geographical areas are not taken into consideration.

Although the functionalities of the prototype are limited, the database on which it is built is complete, that is, the Entity-Relationships model (ER model) fully covers the ontology presented in section 3.3.

3.5.3 Prototype structure

To steps followed to developed the prototype are reported in figure 3.19.

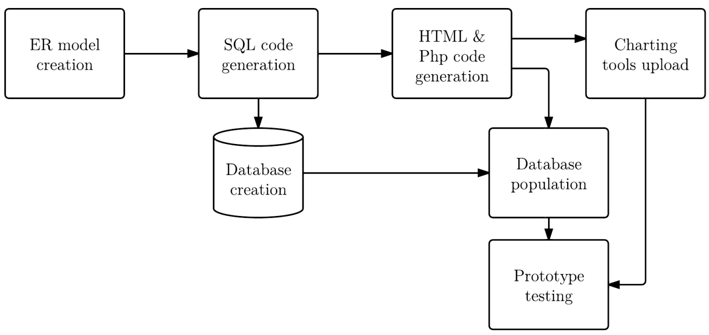


Figure 3.19: The steps undertook to develop the prototype.

The first step has been to build the necessary database. To do so, an ER model of the database has been created using the software "Open ModelSphere". The snapshot of the ER model is presented in figure 3.20.

Once the ER model has been consolidated, the corresponding SQL code has been generated through an apposite function of Open ModelSphere, and uploaded on the SQL database of the website that hosts the prototype. The entire SQL code used is reported in appendix D. Around the SQL database, the different functions for the data input and the data retrieving have been developed. The scripting language

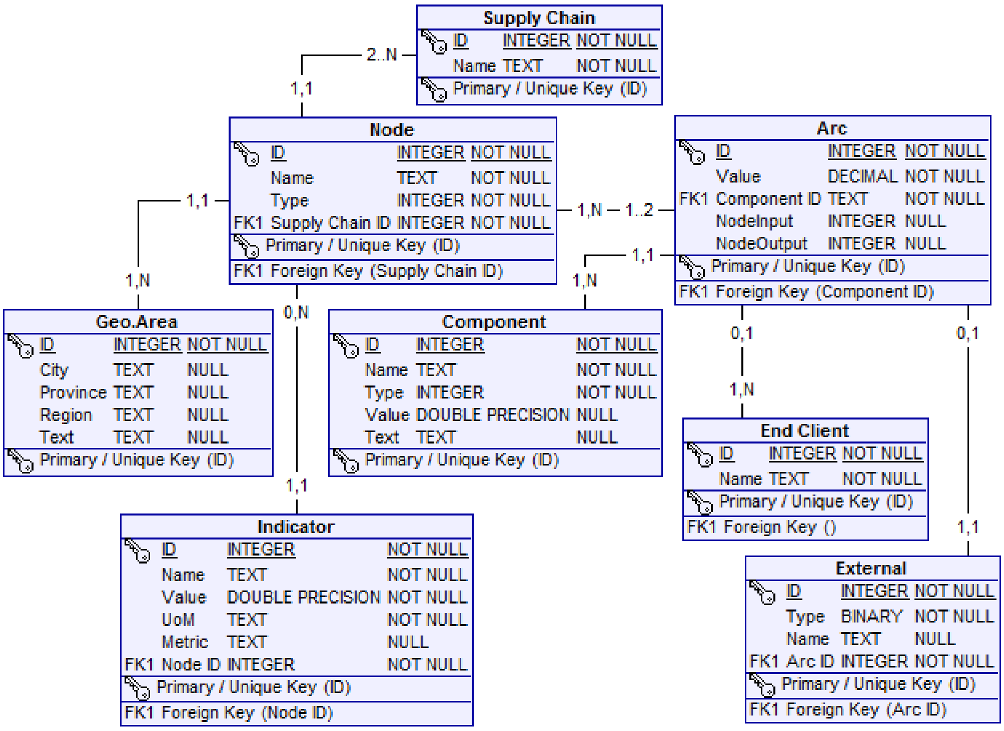


Figure 3.20: The ER model.

chosen is PHP. Once the infrastructure for storing and retrieving data have been developed, it has been integrating with the charting tools. The radar charts are draw through the library "RGraph"[25], while the line and bar charts are draw through the library "Flot"[26]. The last step has been the HTML shell, on which the model outputs one (in SVG), part of the two, and the whole graphical interface to navigate the prototype are based. The formality through which the model has been defined allowed for an easy translation of the analytical parts from the mathematics into the PHP code; as a way of example of such translation, the measure normalization necessary to compute the radar axes values is presented (on the left the analytical equation defined in the previous section, on the right the corresponding PHP code):

$$x_{i,k,radar} = \frac{x_{i,k} - x_{m,k}}{x_{M,k} - x_{m,k}},$$

where:

- $x_{i,k,radar}$ is the normalized, and $x_{i,k}$ the un-normalized, value for node i, indicator k;
- $x_{m,k}$ is the minimum value for indicator k;
- $x_{M,k}$ is the maximum value for indicator k.

```
for($i=0;$i<count($ind);$i++){
 for($j=0;$j<$nodes;$j++){
  $ind[$i][$j]=
  ($ind[$i][$j]-$mm[$i][0])/
  ($mm[$i][1]-$mm[$i][0]);
 }
}
```

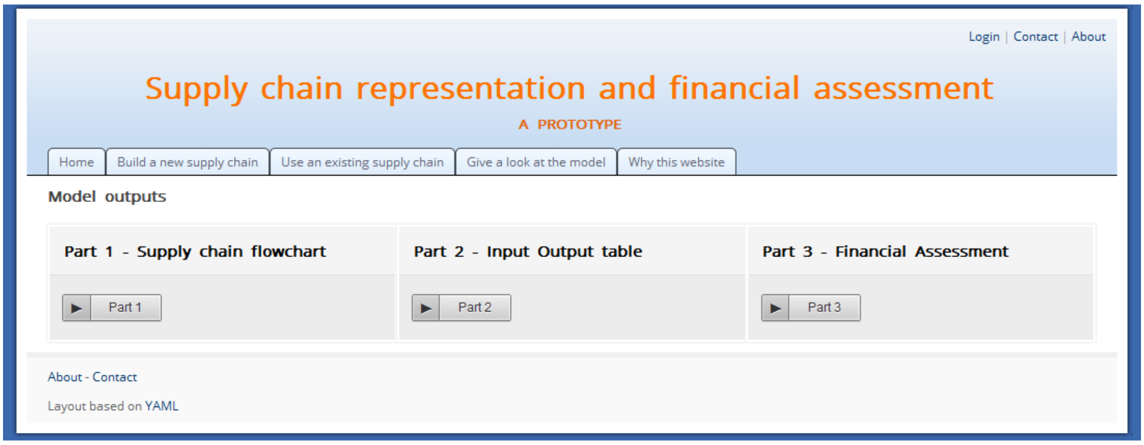
where:

- `$ind[$i][$j]` is the value of indicator `$i`, node `$j`;
- `$nodes` is the number of nodes;
- `$mm[$i][0]` and `$mm[$i][1]` are the minimum and maximum values for indicator `$i`.

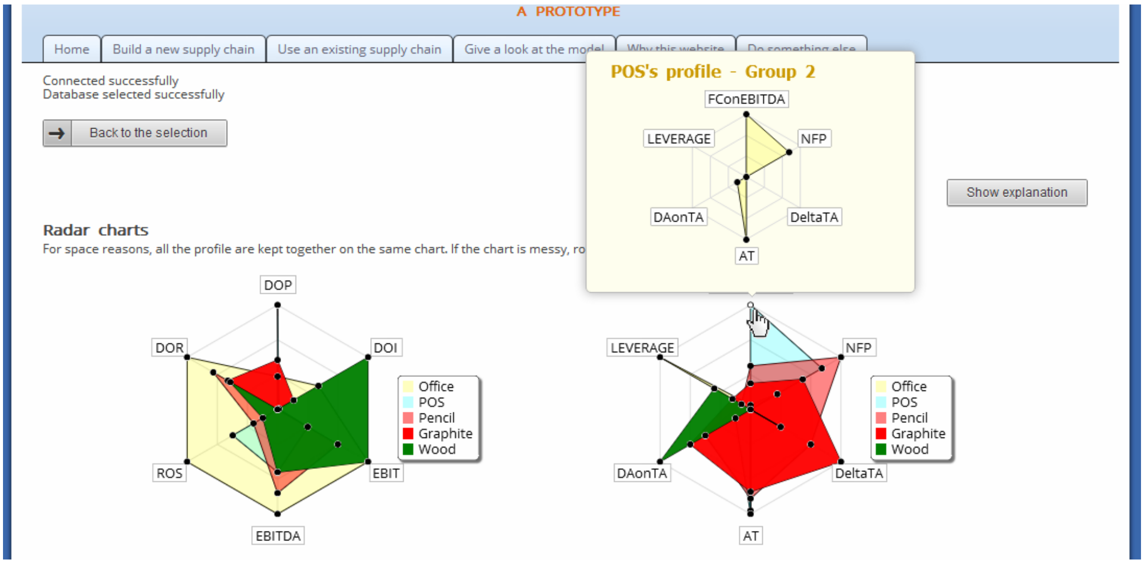
[25] Cf.: `http://www.rgraph.net/`.
[26] Cf.: `http://code.google.com/p/flot/`.

3.5.4 Snapshots

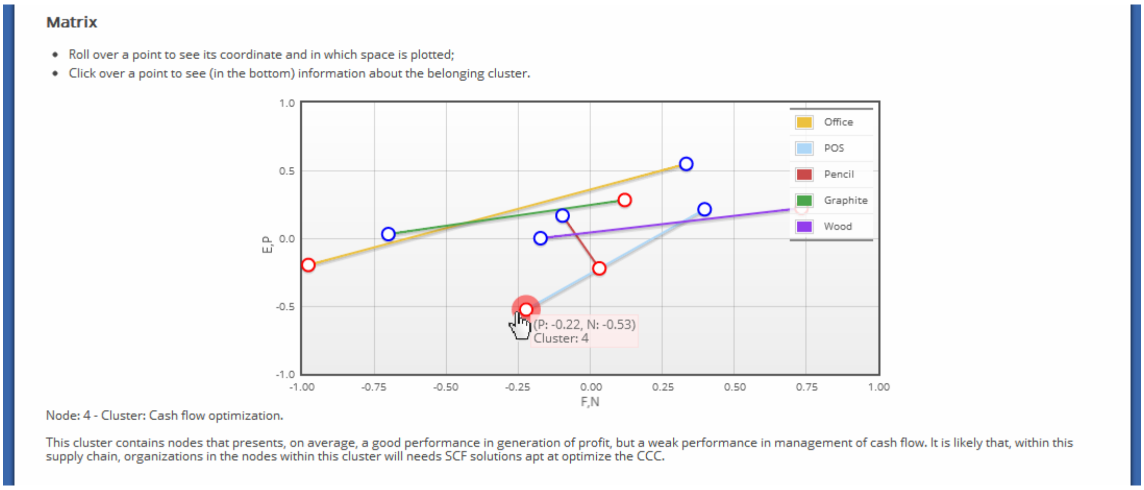
Once the input data have been selected or inserted, the prototype proposes three sections, that correspond to the three outputs of the model. Within the second an the third section, some interaction and dynamic content is added. In particular, within the third output, the user is able to visualize the information about the belonging cluster of each node once she navigates through the different segments. The series of snapshot in figure 3.21 presents some of the prototype interfaces.



(a) Selection of the model output



(b) The radar charts with the interactive tooltip



(c) The financial assessment matrix

Figure 3.21: Snapshots of the prototype interfaces.

Chapter 4

Model application and testing

This chapter illustrates the results of the application of the model to two supply chains, part of the mechanical industry: the manufacture of tubes and the manufacture of machinery for the food industry. Such application has been carried out concurrently to the model development, and represents the model test phase as well. The chapter is divided into two parts: the first one describes the application context, the second presents the results of the such application.

This work, as already mentioned, focus on two sectors: the manufacture of tubes, and the manufacture of machinery for the food and beverage industry. Before entering in the detail of the analysis of these two sectors in Italy, a panoramic of the mechanical industry and of its supply chain is provided[1], followed by the definition of the mechanical industry object of this work.

4.1 The mechanical industry in Italy and its Supply Chain

The mechanical industry supply chain in Italy is known to have the so-called "triangular" form, represented in figure 4.1: in an hypothetical chart on which the x-axis represents the number of firms at each tier, and the y-axis represents the level of the tiers in the production process, we have, nearest the origin, the Metallurgy, with a low number of firms (often with the structure of a multinational corporation), then the distribution tier, composed by stockists and the service centers (the latter divided in primary, secondary, and tertiary), with an increased number of firms, to conclude with the a possible last tier of small but numerous firms that operate the last, small, jobs on the products before they are delivered to the final customers, and that are usually clustered within a restricted number of brands (therefore the number of brands has its maximum in the second sector of this chain).

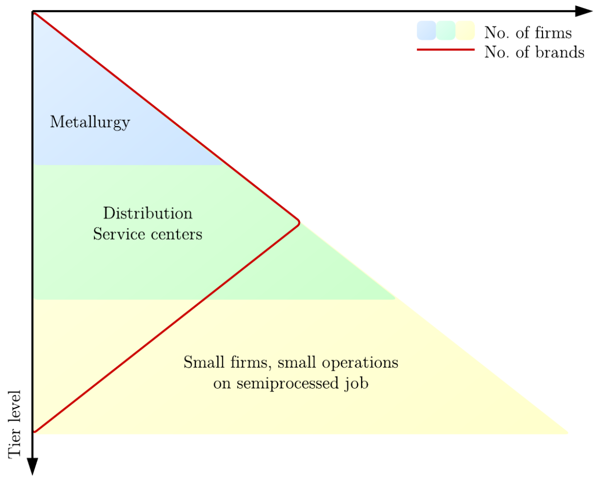


Figure 4.1: The triangular metal-mechanical supply chain.

Source: elaborated by the author

After this last tier, the products exit the mechanical supply chain (sometimes within the mechanical industry itself), to find two (non mutually exclusive) usages: components in other production processes, and investments in tangible assets, i.e., tools, equipments, and machinery used to operate on products. Such output markets are:

- Automotive and transportation; in this market (that, to be precise, is not outside the general definition of mechanical supply chain, cf. section 1.7.1), the outputs of the supply chain described above find both applications: components in the production process (e.g.: metal structure, engines, parts of engines, transmission, and so on), and machinery, tool, and mechanical instrument;

- Furnishing and every day items; in this market, steel and aluminum (and aluminum alloys), have the widest application both as part of products (furniture or part of furniture pieces), and as machinery and tools to operate on WIP in the realization of final products based on other materials (e.g.: wood);

[1]The references of this chapter, if not otherwise specified, come from the body of knowledge constituted by the interview (cf.: section 2.2.7).

- Hydraulic, engineering and construction; specialized jobs produced in the last tier of the triangular supply chain presented above are particularly common in this market, together with an heavy utilization of tubes in the hydraulic jobs, and machinery as assets to be used on construction sites;
- Electronics, office equipment, household appliances; electronic components constitute the base of computers, telecommunication means, as well as television, radios, and all the office equipments and home appliances; they are built usually in steel or steel alloys. Part of machinery and tools are as well product of the mechanical industry;
- Energy supply and electrotechnics; this market (characterized by strict requirements in terms of specification of products) makes a great use of steel and steel alloys, that represent the ideal material in the optimization of the trade-off between the adaptability of the material and its resistance. In the electrotechnics components of steel alloys with high conductivity, engines, generators, voltage transformers, accumulators, and other similar machinery are particularly used. Part of machinery and tools are as well product of the mechanical industry;
- Other sectors; there is a long list of markets that utilize the output of the supply chain described above as tangible assets: machinery, tools, equipments are often product of the mechanical industry supply chain: depending on the typology of the machinery, size, specialization and so on, the asset may come from intermediate as well as from the last level of the triangular supply chain.

This list, summarized in table 4.1, shows how the mechanical industry has a predominant direct role in most of the production industries; with the rise of personal computer and telecommunication means it has an indirect role in almost every branch within the classification of economical activities.

Output Market	Components	Machinery, tools	Output transferred[1] [mlo. of €]
Automotive	X	X	2875
Furnishing and every-day items	X	X	1281
Hydraulic and engineering & contracting	X	X	1641
Electronics, office equipment, and appliances	X	X	5784
Energy and electrotechnics	X	X	5671
Food industry		X	
Chemical		X	
Paper industry		X	
[...]		X	

[1] Is the amount of output produced by the mechanical industry transferred (as *intermediate output*) to other industries. Cf.: Il sistema delle tavole di input-output [2011], last data available: 2005.

Table 4.1: Main output markets of the mechanical industry.

4.2 Definition of the part of mechanical industry object of this work

The first section of this chapter presented a general picture of the supply chain of the mechanical industry in Italy; this one, instead, provides the definition of the part of this industry object of this work. As stated above, the "core" definition of the mechanical industry includes two great sectors: metallurgy and manufacture of mechanical products (the latter sometimes called simply "mechanical industry", in a narrower sense, and spanning from equipments to the automotive).

The part of such industry considered in this work is much narrower than the entire industry, but still crosses its two great sectors. Such part of the industry can be naturally divided into two groups, called *base groups*:

- Manufacture of tubes and pipes - included into the metallurgy

- Manufacture of machinery for the food industry - included into the manufacture of mechanical products

To be aligned with the definitions presented in the literature review (cf. section 1.7.1), the ATECO codes used in this work are presented below. Such codes, that represent the formal definition of the part of mechanical industry object of this work, have been selected following two rules:

1. The code should be included in the "core" definition of mechanical industry (cf. table 1.12);
2. The code should encompasses organizations that are possible suppliers or clients of the organization within the two base groups.

The ATECO codification system selected is the 2002 edition, and the level of detail has been set to the 4-digits level[2]; the complete list of codes extracted is summarized in table 4.2[3]. For each code, the reference group number is provided; a reference group is a group composed by one or more codes kept together *a priori* to facilitate the analysis.

Code	Description	Group	No. of firms[1]
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	1	189
2912	Manufacture of pumps and compressors	1	581
2913	Manufacture of taps and valves	2	485
2914	Manufacture of bearings, gears, gearing and driving elements	3	341
2852	General mechanical engineering	4	7309
2862	Manufacture of tools	4	769
2811	Manufacture of metal structures and part of structures	5	4717
2863	Manufacture of locks and hinges	5	183
2953	Manufacture of machinery for food, beverage, and tobacco processing	6	833
2742	Aluminum production	7	143
2743+2744	Lead, zinc, and tin production + Copper production	7	22
2751	Casting of iron	7	137
2752	Casting of steel	7	27
2753	Casting of light metals	7	135
2874	Manufacture of fasteners, screw machine products, chain, and springs	8	410
2721+2722	Manufacture of cast iron + steel tubes	9	126
2732	Cold rolling of narrow strip	9	38
2733	Cold forming or folding	9	81
2734	Wire drawing	9	106

[1] Before outlier detection procedure application. Cf.: section 2.2.4, page 57.

Table 4.2: ATECO codes used in the analysis

Reference groups 6 and 9 represent the two base groups. Together with the groups coming from the ATECO codes, two other reference groups has been added[4]:

- Group 10 - Service center, manufacture of tubes;
- Group 11 - Stockist, manufacture of tubes.

After having presented the codes downloaded, each base group, with the connected reference groups is analyzed separately.

[2]The name of the code provided here are not translated by the Italian, but correspond to the equivalent NACE code: there is a partial concordance between NACE and ATECO codifications, in particular ATECO 2002 codification equals the NACE Rev. 1.1, up to the 4-digit level; thereby, even if the download technically was done from a list of ATECO codes, they can be identified through the corresponding NACE name , with no loss of generality.

[3]Codes put together (e.g.: 2743+2744) represent a single extraction.

[4]For more information about these two groups, cf.: section 2.2.6, page 60.

4.3 Manufacture of Tubes in Italy

The manufacture of tube supply chain resembles, in part, the general structure of the mechanical supply chain presented above. In fact, three groups can be identified between the producer of tubes and the customers: the manufacture of tubes, the stockists, and the services centers. The manufacture of tubes in Italy is defined through the ATECO codes summarized in table 4.3.

Code	Description	No. of firms
2721+2722	Manufacture of cast iron + steel tubes	126
2732	Cold rolling of narrow strip	38
2733	Cold forming or folding	81
2734	Wire drawing	106

Table 4.3: ATECO codes for manufacture of tubes

It comprises around 350 active firms, concentrated in the north of Italy[5].

The tube manufacturers is part of the metallurgy sector[6], and therefore shares the common characteristics of such sector:

- Strong economies of scale, that make paramount to increase in size both vertically and horizontally;
- Low differentiation level of products, sometimes seen as a valueless option;
- Tendency to focus on cost leadership as strategy
- Tendency to the optimization of the product flows towards the output markets, and (recently) integration in the distribution sector, especially towards the stockists.

Specifically speaking about the tube manufacture, a first insight on the classification of manufacture of tube (Brasili et al. [2011], Wouters et al. [2010]), divides it based on a matrix, in which the axes are the number of markets in which the firm operates, divided into *Local* (low) *International* (high), and the number of businesses[7], divided into *Specialistis* (low), and *Generalists*, (high). The matrix and the position of the tube manufacture is shown in figure 4.2.

None of the four classes is better off by definition: being a local generalist may be economically sustainable, especially if the economies of scale are not a concern, because it avoids being the target of big players: this is a common situation in the stockists group of the tube manufacture. In the same way, being international means for sure access different markets, but also increase fixed costs and face additional competition.

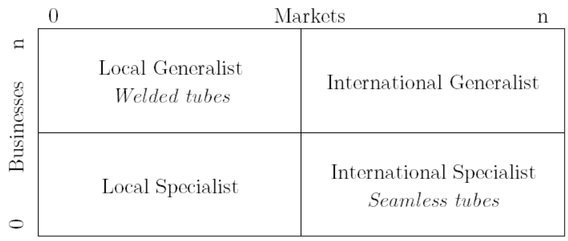


Figure 4.2: Classification of tube manufacture by Brasili et al. [2011].

This matrix introduces the “canonical” categories of tube manufacture: welded tubes and seamless tubes. A different (but not mutually exclusive) categorization divides them into “traditional”, composed by the manufacture of cast iron and steel tubes and the cold rolling of steel strip, and the “innovative”, composed by the relatively new technology of cold forming and drawing. The main differences between the two groups are reported in in table 4.4.

[5] Geographical maps of industry concentration are available in appendix C.

[6] Ten clusters are usually identified in such sector: tubes, stainless steel, ingots, long products (rounds and beams),

	Traditional	Innovative
Type of production	Manufacture of cast iron + steel tubes + cold rolling	Cold forming, drawing
Level of capital intensity	High	Low
Margin applicable	Low	High
Production approach	MTS & MTO	Only MTO
Presence of economies of scale	Yes	No

Table 4.4: Traditional and innovative manufacture of tubes

4.3.1 Raw Material for tube manufacture in Italy

The organizations that provide raw materials for the tube manufacture in Italy are defined through the ATECO codes summarized in table 4.5.

Code	Description	No. of firms
2742	Aluminum production	143
2743+2744	Lead, zinc, and tin production + Copper production	22
2751	Casting of iron	137
2752	Casting of steel	27
2753	Casting of light metals	135

Table 4.5: ATECO codes of raw material for manufacture of tubes

It comprises around 460 firms, concentrated in the north of Italy[5]. Given the framework of tube materials presented above in figure 1.14, the raw materials included in this analysis are steel, cast iron, aluminum, and aluminum alloys. Firms in this group are characterized by a strong integration.

4.3.2 Screws and fasteners

Another source of raw materials for the production of tubes, even if secondary to the metal casting, is the production of screws and fasteners, composed by the ATECO code presented in table 4.6.

Code	Description	No. of firms
2874	Manufacture of fasteners, screw machine products, chain, and springs	410

Table 4.6: ATECO code for the production of screws and fasteners

This group comprises around 400 firms distributed mainly in the north of Italy, especially in the Lombardy region[5]. On average, organizations in this group are characterized by having the 50% of production following the logic called *make to stock*, and the remaining 50% the logic *make to order*, usually based on the client's design. The lead time between the design and engineering phase to the end of the production phase of a new product can take up to 3 month, with most of the time devoted to the procurement phases, and only 10 to 15 days devoted to the production launches. This group is characterized by a strong international vocation, although typical only of the specialized production.

4.3.3 Distribution and service center

The distribution system of the tube manufacture is peculiar: it is composed by two groups: stockist and service center. A stockist is a distributor that acquire and sell products without physical modifications,

plain products (coils and metal sheets), forges, wire drawing, steel casting, cast iron casting, precision casting; such clusters are sometimes interrelated: a cluster may be the supplier of another one. Cf.: Bilanci d'acciaio [2011].

[7]For the purpose of this matrix, a business can be defined as a couple of value (product;segment).

while a service center is a firm (generally smaller than the ones of tube production presented above) that acquire products, operate to specialize them, and resell them to clients. Both the groups presents geographical distributions similar to the tube manufacturing one[5].

Stockists

Stockists (Italian: *Distributori dal pronto*) for the Italian mechanical industry can be divided in six clusters:

1. Tubes;
2. Flat products;
3. Inox products;
4. Long products;
5. Generalists;
6. Agents and foreign firms representatives. (Bilanci d'acciaio [2011])

Of course only the tube cluster is of interest for this work; anyway, as for the tube manufacture, they share common characteristics. In particular, the average stockist tends to be strongly fragmented, but highly present in the territory, insomuch as it is, sometimes, a strength; in fact, the average size of a stockist makes it difficult to be acquired by upstream companies willing to expand vertically. On the other side, such size means small capacity of investments, as well as small bargaining power vis-à-vis the producers.

Service Centers

Service centers (Italian: *centri servizio*) for the Italian mechanical industry are divided into four clusters:

1. Flat products - carbon coils and steel sheets;
2. Inox products;
3. Long products - round (reinforced concrete);
4. Long products - beam and steel sheets.

Technically speaking, service centers specialized in tubes belong to the first cluster; however, the reality of service centers in Italy do not usually present such clear clustering; it is common for them to provide services and products that span over more than one cluster.

As mentioned above, the service centers are not pure distributors: they merge minor transformations on products with distribution services (Brasili et al. [2011]). Anyway, this peculiarity, that was a typical source of success for them, is threatened. Typically, the service centers add value to the output of the tube manufacturers, specializing their product. Nevertheless, the tube manufacturers are characterized by the need for an increasingly level of economies of scale, that pushes them to expand both vertically and horizontally, acquiring similar business and increasing the number of reference produced and the range of products, and sometimes distributing them on their own, entering in contrast with the service centers. Analyses focused on this contrast foresee that the service centers will evolve diminishing their distribution services and increasing their specialization ones. In particular, they should have, in order to survive, a paradigm shift: from different product specializations, typically needed by the same pool of customers, to a lower number of specializations, achievable with similar and sophisticated technology, offered to different, even heterogeneous, pools of customers. This should allows them to reach an higher level of economies of scale, to provide customers specialized references at a lower cost. The tube manufacturers should be less prone to offer the same references, because of the cost of the technology needed that, being tied to a specific specialization, would be uneconomical for them (Brasili et al. [2011]).

Should be noticed that the same solution cannot be applied to the stockists. The contrast between the tube manufacture and the stockists is still of unclear outcome: as already mentioned, the tube manufacture wishes to acquire the stockists present on the territory, but the size and number of the latter make the operation highly costly. Such situation has been translated, in the last years, in an economical pressure of the tube manufacturers on the stockists, that therefore suffered worse performance, especially in the management of cash flows, respect to the other group composing the supply chain.

4.4 Manufacture of machinery for the food industry

The manufacture of machinery for the food industry in Italy is composed by the ATECO code summarized in table 4.7.

Code	Description	No. of firms
2953	Manufacture of machinery for food, beverage, and tobacco processing	833

Table 4.7: ATECO codes for the manufacture of machinery for the food industry

As can be understood from the name, this set, including also the tobacco processing, is actually wider than the one conceptually object of this work; unfortunately no further subdivision of this single code are provided in the NACE/ATECO codification systems. This group comprises around 800 firms, located in the north of Italy, especially in the area of Emilia Romagna, Lombardy, and Veneto. The higher-than-the-average presence in the Emilia Romagna area (around one third of the firms), respect to the average of the mechanical industry, is probably to be attributed to the food industry itself, strongly presence in this region[5].

This type of industry is strongly based on the production logic *make to order*, with use of the warehouse for small and standard components, products, and spare parts. These firms are strongly focused on the preservation of the known-how: in fact, on average, the main cost items in the income statement are the labor cost and the expenses for research and development; the profit generation is hardly achievable through economies of scale, but is usually pursued trough obtaining a *premium price* for the design and the features of the products.

For this reason one of the concerns of these companies is the protection of the intellectual property, especially for that part of revenues generated abroad. This concern for intellectual property, together with the structure of the market, pushes companies to pursue premium price through better R&D, creating a conflict of objectives: by one side the companies do not pursue growth at all costs, creating a phenomenon of small companies serving big players within the food industry through small production lots, or single specialized products; on the other side, such small size might become a threat to the companies survival, due to the international competition (especially from the Chinese market), and to the strategic choice of avoiding outsource to preserve intellectual property. For the same reasons, it is not common to use a tier of distributors, even if third-parties may be involved in the realization of production phases, or in the installation of the machinery on the site.

As result also from the literature analysis of this part of mechanical industry, the raw materials and components used by this node are numerous. The main groups are analyzed in the next sections[8].

4.4.1 Engines, turbines, pumps and compressors

The first set of suppliers for the manufacture of machinery for the food industry is composed by the two ATECO codes summarized in table 4.8.

Code	Description	No. of firms
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	189
2912	Manufacture of pumps and compressors	581

Table 4.8: ATECO codes for the production of engines, turbines, pumps, and compressors

[8]Please note that the groups of the previous supply chain: “manufacture of tubes”, “metal casting”, and “screw and fasteners” (reference groups 7, 8, and 9) are also suppliers of the manufacture of machinery for the food industry, but comprehensibly their description is not repeated again in this section.

It provides critical components of high complexity. This group comprises around 770 firms distributed mainly in the north of Italy, especially in the provinces of Milan, Brescia, and Novara[5].

4.4.2 Taps and valves

The second set of suppliers for the manufacture of machinery for the food industry is composed by the ATECO code presented in table 4.9.

Code	Description	No. of firms
2913	Manufacture of taps and valves	485

Table 4.9: ATECO code for the production of taps and valves

This group comprises around 480 firms distributed mainly in the north of Italy, especially in the provinces of Novara, Brescia, and Milan[5]. The main characteristic that distinguishes this group from the other is that it is considered the world leader in this type of products, with the production typically carried out in Italian sites.

4.4.3 Bearings, gears, gearing and driving elements

The third set of suppliers for the manufacture of machinery for the food industry is composed by the two ATECO code summarized in table 4.10.

Code	Description	No. of firms
2914	Manufacture of bearings, gears, gearing and driving elements	341

Table 4.10: ATECO code for the production of bearings, gears, gearing and driving elements

This group comprises around 340 firms distributed mainly in the north of Italy, especially in the provinces of Bologna, Milan, Turin, and Brescia[5].

4.4.4 General mechanical engineering and tools

The fourth set of suppliers for the manufacture of machinery for the food industry is of a strongly general nature, and its inclusion in this schema requires further explanation. The ATECO codes who compose it are summarized in table 4.11.

Code	Description	No. of firms
2852	General mechanical engineering	7309
2862	Manufacture of tools	769

Table 4.11: ATECO codes for the production of bearings, gears, gearing and driving elements

This group comprises around 8000 firms distributed mainly in the north of Italy; however, together with the next group (metal structure), this group is one of the most evenly distributed on the Italian territory, with zone of medium-high concentration also in the center-Italy, especially around the provinces of Rome and Naples[5].

This group is of a general nature, as testify by the great number of firms included, but its inclusion in the set of supplier of the manufacture of machinery for the food industry cannot be avoided; in fact, this ATECO includes organizations that perform processes or produce products of primary importance for the manufacture of machinery for the food industry. The main ones are:

- Blades and parts of blades (excluded cutlery);
- Cutting tools;

- Grips;
- Cutting, welding, jointing of metal parts.

4.4.5 Manufacture of locks and hinges

The fifth set of suppliers for the manufacture of machinery for the food industry is composed by the two ATECO codes summarized in table 4.10.

Code	Description	No. of firms
2811	Manufacture of metal structures and part of structures	4717
2863	Manufacture of locks and hinges	183

Table 4.12: ATECO codes for the production of metal structure

This group comprises around 4800 firms distributed mainly in the north of Italy, especially in the provinces of Milan, Brescia, and Bergamo[5]. This group, characterized by an low level of customization, is critically exposed to low-prices importation, especially from oriental countries.

4.5 Model application

The previous section presented the supply chain understanding built during the development of the model and its concurrent application. This section will present the results of such application.

4.5.1 Two important notes

Firstly, as said a numerous times, the supply chain object of this work is divided in two, connected, parts: the manufacture of tubes, and the machinery for the food industry. This arises a problem of treatment: should the model be applied to the whole set, or to the two subgroup separately? The choice is to propose the first output, the supply chain flowchart, applied both to the whole supply chain and to the two parts, in order to highlight how the model output is linked to the specific supply chain, and changes when the focus point changes. The node exchanges matrix, instead, is presented only in the aggregated form (both supply chains together), given that a disaggregation would have not added value. Ultimately, the third output is directly developed in the disaggregated form, to improve readability of the results and an higher tailoring of messages on the single parts. When the two parts are in the disaggregated form, for seek of simplicity, they will be called *manufacture of tube supply chain*, and *manufacture of machinery for the food industry supply chain*.

Secondly, to improve readability and save precious space, the name of the reference groups may be shortened to their ID. As a way of reference for the whole chapter, IDs and complete name are provided in table 4.13. Reference for the extended name and metrics for the measures used, instead, are reported in table 3.4, at page 80.

4.5.2 Model output part 1

The model output part one consists of the supply chain flowchart. Figure 4.3 presents the flowchart of the aggregated supply chain, with arc values, while figure 4.4, and 4.5 respectively focus on the single supply chain of the tube and machinery for the food industry.

Different consideration can be made:

- Should be noticed how the node "Manufacture of tubes" changes position from the tube to the machinery for the food industry flowcharts: that is because in the former it represents the focal node of the supply chain, while in the second only a supplier;
- The service centers present the peculiar nature of both manufacturers and distributors, and therefore are placed across the correspondent swim-lanes;

ID	Extended name
G1	Engines
G2	Taps and valves
G3	Gearings
G4	General mechanical engineering
G5	Metal structures
G6	Machinery for the food industry
G7	Metal casting
G8	Screws and fasteners
G9	Tube manufacturing
G10	Service center - tubes
G11	Stockists - tubes

Table 4.13: IDs for supply chain nodes.

- The presence of multiple customers nodes has representation purpose only, no arc values have been actually estimated for different typologies of customers;
- The two supply chain presents two different dimensions of complexity, as already anticipated: for the tube supply chain it is a complexity in the relationships among players in the manufacturing-distributor tier, for the machinery for the food industry, instead, it is a complexity in the numerous suppliers (note that only the ones belonging to the mechanical industry are here represented).

Clearly, the area of the flowchart that presents an higher level of complexity, attracts also the majority of the consideration, and is more likely to find in it the critical point of non-canonical financing solutions, as will be clearer in the rest of this chapter.

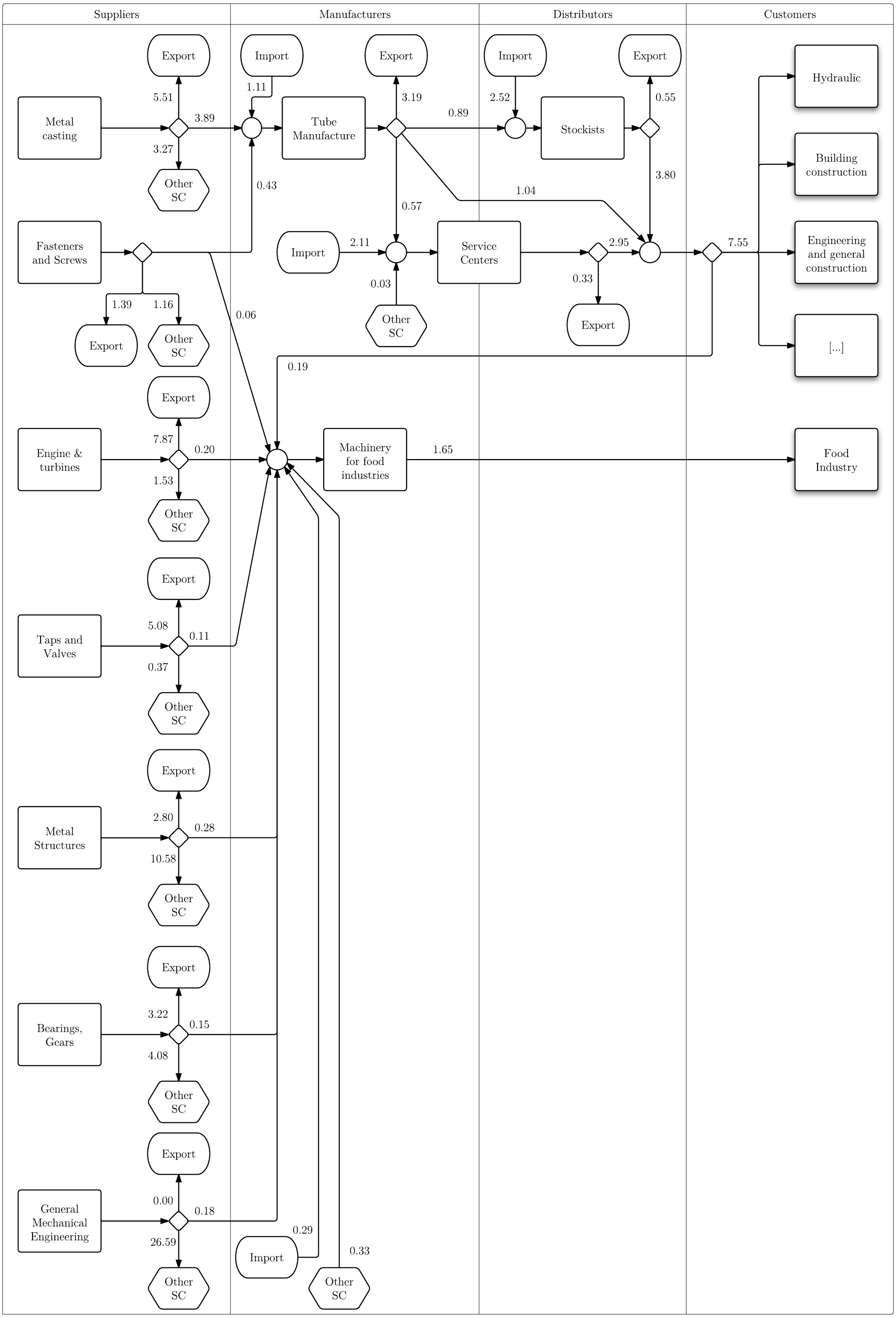


Figure 4.3: The flowchart for the two supply chains object of this work (values in billion of €).

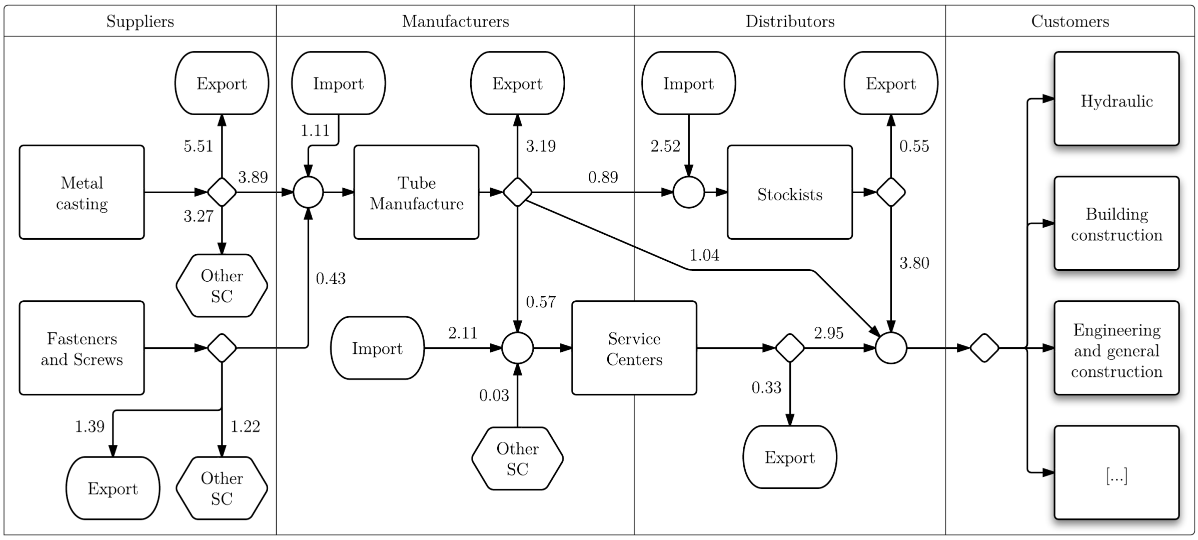


Figure 4.4: The supply chain flowchart for the manufacture tube supply chain (bln €).

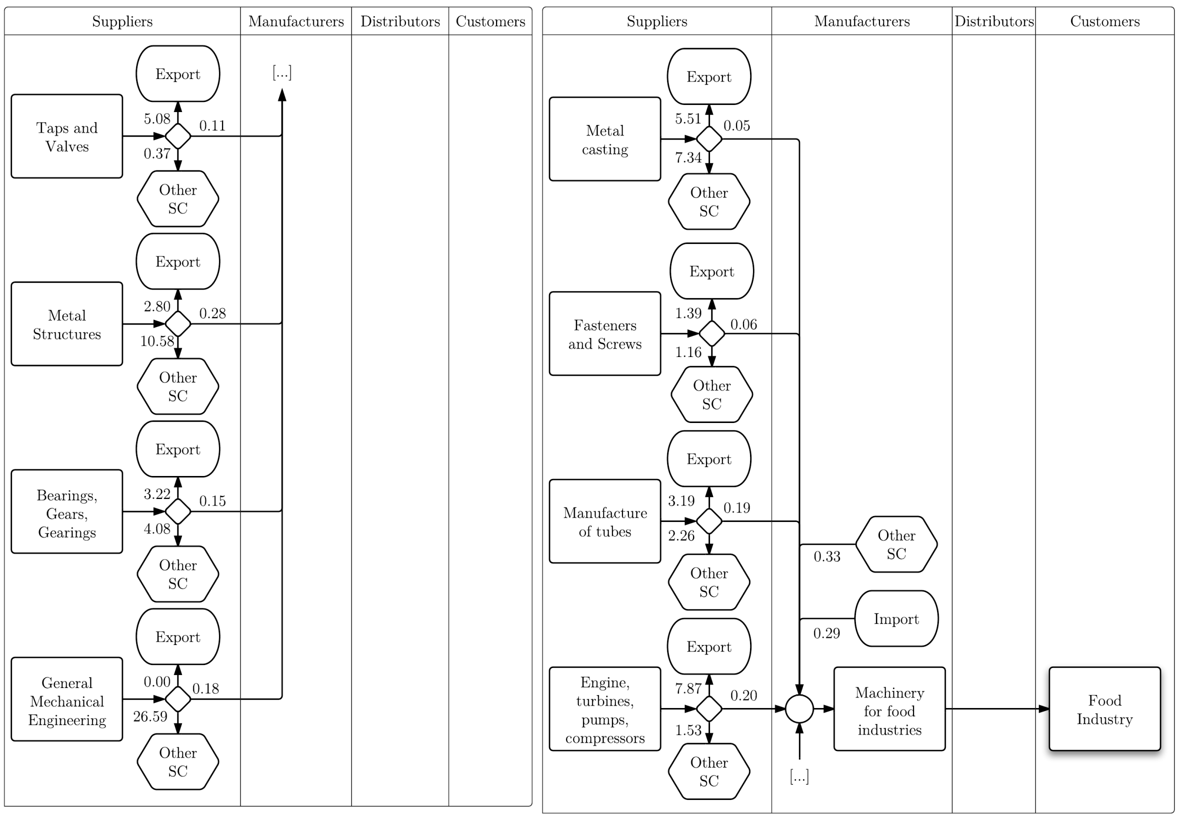


Figure 4.5: The supply chain flowchart for the machinery for the food industry supply chain (bln €).

4.5.3 Model output part 2

The second output of this application of the model is the node exchanges matrix (reported in table 4.14), together with the production coefficients matrix (reported in table 4.15).

from $i \downarrow$ to $j \rightarrow$	G6	G9	G10	G11	Export	Other SC	Customers	Total
G1	0.20	-	-	-	7.87	1.53	-	9.60
G2	0.11	-	-	-	5.08	0.37	-	5.57
G3	0.15	-	-	-	3.22	4.08	-	7.46
G4	0.18	-	-	-	0.00	26.59	-	26.77
G5	0.28	-	-	-	2.80	10.58	-	13.66
G6	-	-	-	-	2.25	-	1.65	3.90
G7	0.19	3.89	-	-	5.51	3.27	-	12.85
G8	0.06	0.43	-	-	1.39	1.16	-	3.04
G9	0.05	-	0.57	0.98	3.19	-	0.99	5.78
G10	0.03	-	-	-	0.33	-	2.95	3.30
G11	0.05	-	-	-	0.55	-	3.80	4.40
Other SC	0.33	-	0.03	-	-	-	-	0.35
Imports	0.29	1.11	2.11	2.52	-	-	-	26.19
Total	1.92	5.43	2.71	3.50	32.19	47.58	9.39	

Table 4.14: Node exchanges matrix for the supply chain object of this work (bln €).

from $i \downarrow$ to $j \rightarrow$	G6	G9	G10	G11
G1	0.05	-	-	-
G2	0.03	-	-	-
G3	0.04	-	-	-
G4	0.05	-	-	-
G5	0.07	-	-	-
G6	-	-	-	-
G7	0.05	0.67	-	-
G8	0.01	0.07	-	-
G9	0.01	-	0.17	0.22
G10	0.01	-	-	-
G11	0.01	-	-	-
Other SC	0.08	-	0.01	-
Import	0.07	0.19	0.64	0.57
Total	0.48	0.93	0.82	0.79
Ones' complement	0.52	0.07	0.18	0.21

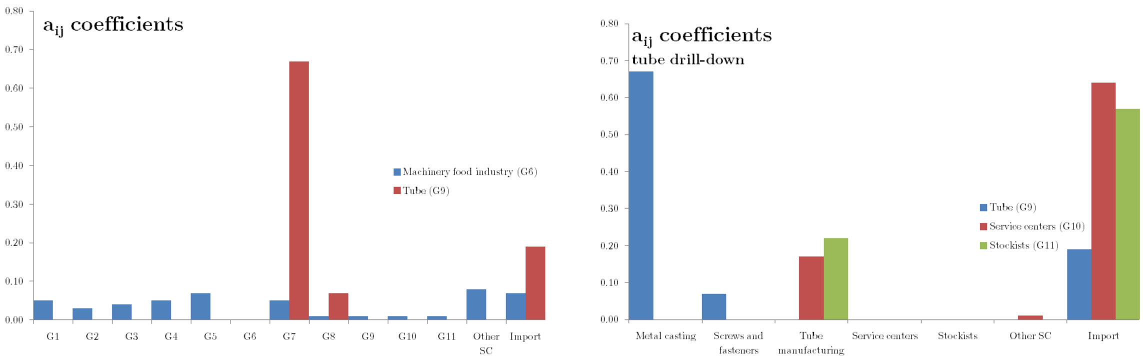
Table 4.15: Production coefficients matrix for the supply chain object of this work.

Note that, as already stated in the previous chapter, columns for which, by definition, $x_{ij} = 0 \; \forall i$ or $x_j = 0$, are not reported in table 4.15. Other considerations can be drawn upon these tables:

- The production coefficients matrix represents the same differences in the areas of complexity of the two supply chains presented in the flowchart (cf. also: figure 4.6(a)). Moreover, the tables referring to the machinery for the food industry supply chain mirrors what emerged through the analysis of secondary sources: the a_{ij} coefficients of this supply chain are all low, and sum up at less than 0.5; this confirms that, on average, the raw materials cost is not a critical cost item for this node[9];

[9]As stated in the previous section, the most critical cost item for this node is the R&D expenses, followed by the manpower costs.

- On the other side, the tube supply chain presents a clear dependency from the metal casting, although this was easily understandable;
- Drilling-down on the tube only (cf.: figure 4.6(b)), it is possible to see how the structure of the three main nodes differs: while the tube have links with the national raw materials suppliers, the service centers and stockists do not present a similar, relevant, link. Furthermore, the distribution tier relies strongly on importation. This suggests that the link between the manufacturers of tubes and the two distribution nodes is not that strong.



(a) Both supply chains

(b) Tube supply chain

Figure 4.6: a_{ij} coefficients for the supply chins object of this work.

4.5.4 Model output part 3

Manufacture of tubes

The third output of the model is the financial assessment of the supply chain. The radar charts (cf.: section 3.4.3 at page 79) for the manufacture of tubes are presented in figure 4.7.

The rough data (equal to the arithmetic mean, per node per measure) are summarized in table 4.17; the radar values ($x_{i,k,radar}$), per node per measure, are summarized in table 4.18; as a way of example, the radar value "EBITDA" for the node "Manufacture of tubes" (G9) is calculated as:

$$x_{9,EBITDA,radar} = \frac{x_{9,EBITDA} - x_{m,EBITDA}}{x_{M,EBITDA} - x_{m,EBITDA}} = \frac{1516 - 605}{2005 - 605} = 0.65. \qquad (4.1)$$

From the radar values is possible to calculate the four parameters, using equation 3.15 on page 82, which values per each node are presented in table 4.16.

Node	F	E	P	N
G7	0.23	0.17	0.19	0.4
G8	-0.2	-0.33	0.42	-0.33
G9	0.24	0.19	-0.33	-0.05
G10	-0.36	0.22	-0.23	-0.24
G11	-0.06	-0.38	-0.95	-0.27

Table 4.16: Values for the four parameters for the manufacture of tubes.

The matrix built from them is presented in figure 4.8(c): it is the overlap of the other two matrices reported in figure 4.8(a) and 4.8(b). As a way of example, the calculation of the parameter F for the node "Manufacture of tube" (G9) is:

$$g_F(\mathbf{x}_9) = \frac{\sum_{k \in F}(2 \cdot x_{9,k,radar} - 1) \cdot d_k}{3} = \\ = \frac{(2 \cdot 0.12 - 1) \cdot 1 + (2 \cdot 0.27 - 1) \cdot (-1) + (2 \cdot 0 - 1) \cdot (-1)}{3} = 0.24. \qquad (4.2)$$

Node	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
G7	138.39	114.74	164.07	744.91	2005	0.02	0.05	1.84	3600.2	0.06	0.05	1.01
G8	225.92	124.86	218.21	291.25	605.55	0.05	0.19	2.68	950.99	0.09	0.04	0.95
G9	119.92	112.72	141.63	786.47	1516.03	0.03	0.13	1.82	4189	0.06	0.03	1.07
G10	88.67	127.96	132.26	1019.36	1776.48	0.02	0.17	1.02	7434.53	0.34	0.02	1.17
G11	80.74	121.74	130.74	647.6	1025.27	0.02	0.17	2.2	3301.87	0.04	0.02	1.16

Table 4.17: Arithmetic means per measure per node.

Node	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
G7	0.4	0.13	0.38	0.62	1	0.13	0	0.49	0.41	0.08	1	0.29
G8	1	0.8	1	0	0	1	1	1	0	0.18	0.95	0
G9	0.27	0	0.12	0.68	0.65	0.46	0.59	0.48	0.5	0.06	0.51	0.56
G10	0.05	1	0.02	1	0.84	0	0.86	0	1	1	0.16	1
G11	0	0.59	0	0.49	0.3	0.14	0.84	0.71	0.36	0	0	0.93

Table 4.18: Radar axis values per measure per node.

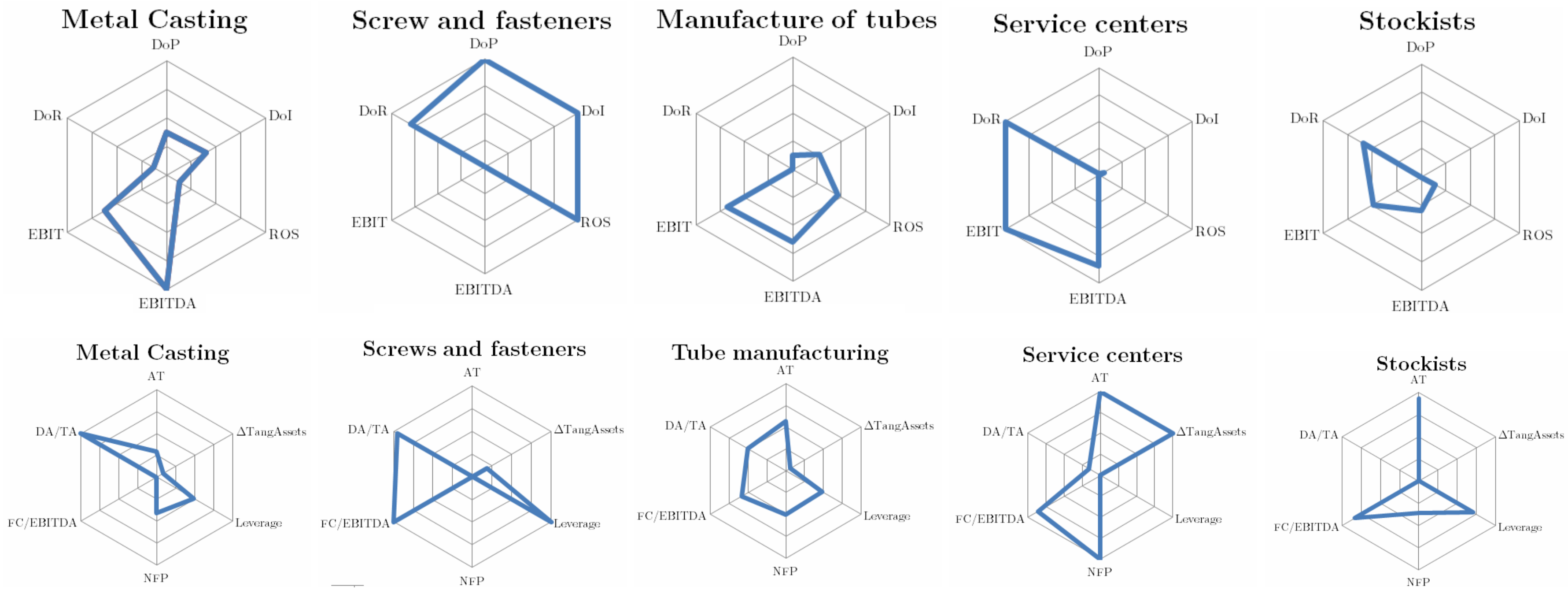
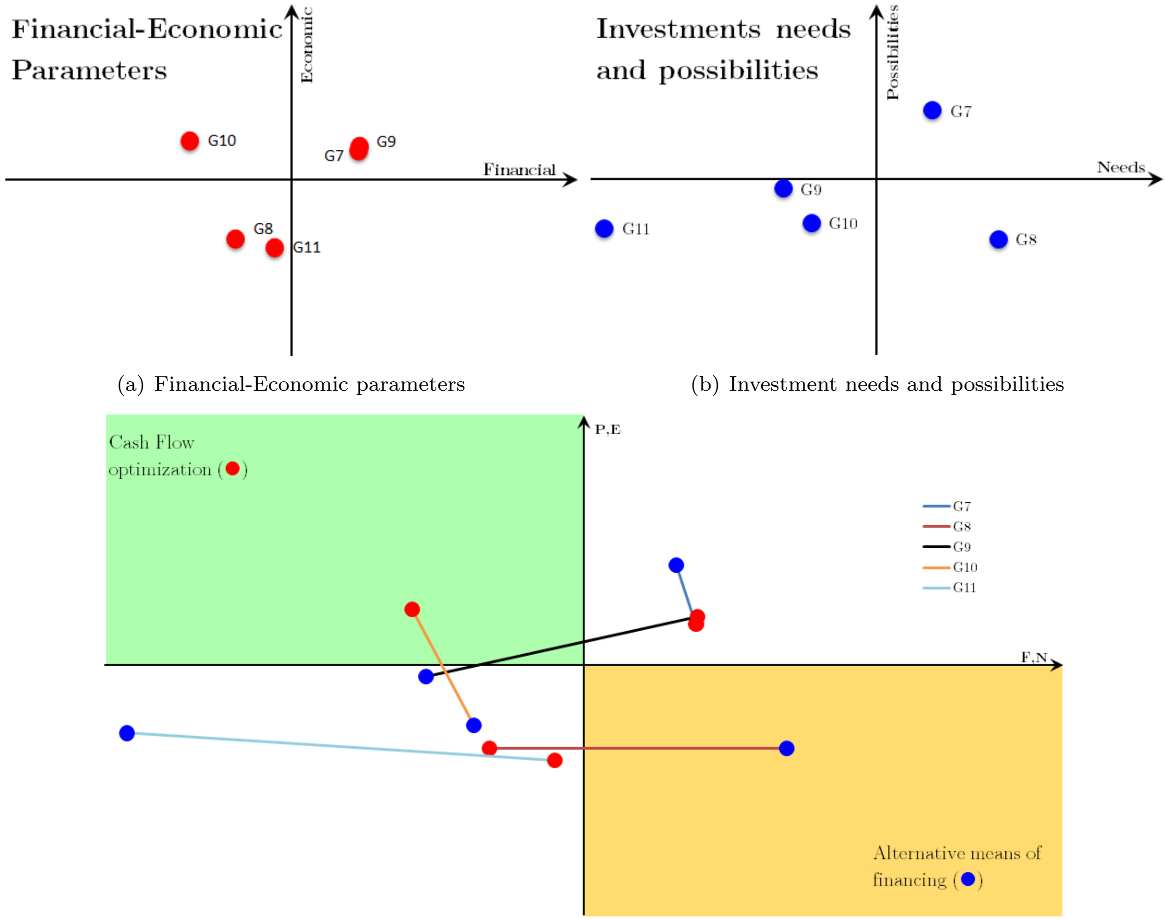


Figure 4.7: Radar charts for the tube manufacture supply chain.



(a) Financial-Economic parameters (b) Investment needs and possibilities

(c) Financial assessment matrix

Figure 4.8: The financial assessment matrix and the two scatter plots from which it derives.

Considerations The considerations that can be drawn about this and the other outputs of this model absolve the testing function within this work. As will be clear, such considerations are in line with the messages collected through interviews and analyses of secondary sources: the testing part therefore can be considered successful, although not conclusive.

Before entering in the detail, let's state clearly to which cluster each node belongs[10], as reported in table 4.19.

Node		Parameters					Cluster
		F	E	P	N		
G7	Metal casting	H	H	H	H	1	High performer
G8	Screws and fasteners	L	L	L	H	5	Low performer
G9	Tube manufacture	H	H	L	L	4	Doubtful case
G10	Service centers	L	H	L	L	7	Cash flow optimization
G11	Stockists	L	L	L	L	5	Low performer

Table 4.19: Belonging cluster for each node of the manufacture of tube supply chain.

The structure of this supply chain mirrors what presented in the context section: the distribution suffers problems related to the strength of the upstream players: the metal casting and manufacture of

[10]To see how node are allocated to cluster, please cf.: table 3.7, page 86.

tubes nodes (the screws and fasteners nodes, in the end, is quite secondary) have both strong profit generation capability respect to the other nodes, while both the distributors nodes suffer weak performances, especially in the management of cash flows. In particular:

- Metal casting: is an high performer, the successful achievement of an high level of economies of scale allows it to generate profit, and the primary role gathered in this and other supply chains during the years permits it to manage cash flow at its benefit. Its comprehensibly strong investment needs are compensated by its high possibility of access canonical financing solutions;
- Screws and fasteners: is a low performer, in particular its strong need for capital are not compensated by the possibility increase debt through canonical financing solutions. It is known that this node is divided into two groups: firms that operate in the logic of the *make to order* and firms that operate in the logic of the *make to stocks*; it should be inquired if the former case (that operate on non-standard commission orders, and that seems to require a strong relationships with specific buyers) can be part of SCF programs aimed at provide alternative means of financing, coming from the buyers of the specialized parts. However, this node is quite secondary in this picture, further inquiry should begin from an *ad-hoc* application of the model;
- Tube manufacture: this node presents strong profit generation capability, as it is composed by companies similar to the metal casting one, but weak investment needs, as well as weak possibility of reach capital through canonical means. There can be different explanation to this weak investment needs, first of which a lower necessity of renewing production equipment. However, the important point is that is it seems, given the supply chain understanding built so far, that this node, as well as the metal casting node, generated in the years a sort of strength that allows it to stress the relationship with the distribution tier. Moreover, this node situation in the investments group of measures, with $N = -0.05 > P = -0.33$) makes it close to the cluster: "Alternative means of financing"; it should be inquired if this slight lack of canonical capital-reaching possibilities is not a cause of the suboptimal conditions in the economical relationships among this node and the distribution tier;
- Service centers: the peculiarity of this node is in its financial-economic position; in fact, having a good profit generation capability, but a weak performance in cash flow management, this node seems to be a better fit (respect to the other nodes) for a cash flow optimization SCF program. Such SCF program could be the solution to one of the main criticality of such supply chain, i.e.: the stressed relation between the manufacture and distribution tier. Being parallel and not exclusive with the paradigm shift analyzed in the previous section, a solution that optimize payable (for the service centers) could decouple the CCC of this relationships, allowing the service centers to be untied from the burden of the financial pressure exercised by the tube manufacture, that seems to be the main cause of weak performance of this node; on the other side, the decouple of the CCC might freed capital for the tube manufacturers, resolving the possible node issue constituted by $P < N < 0$. Size, measures, and policies of such program depend on the unavoidable organization-level analyses;
- Stockists: this node belongs to the cluster called "Low performer"; it is characterized by a weak performance both in terms of profit generation and cash flow management; given the non-manufacturing nature of this node, the investment needs are the lowest of the supply chain; what should be inquired is if a possible SCF solution can be the key to improve the performance of this node. Given the relatively non-existent investment needs, such solution would be similar to the one proposed for the service centers: however, here the solution is more critical for, at least, two points:
  - The node has a weak profit generation, and there are no guarantee that a solution that will improve its financial performance will solve this issue: the causes of the weak economic performance might be due to other variables;
  - The service centers are foreseen to enter in a paradigm shift that may improve their position. Such shift is precluded to the stockists, and this again casts shadows on the possibilities that an SCF solution would be enough to solve the issues.

Strictly speaking, more guarantees of a success of the SCF solution should be found, e.g.: service increase to the final customer due to the resources freed. Apply an SCF solution should bring benefit *to the whole supply chain*, otherwise it may be proven inefficient.

Ultimately, considerations about the three outputs as a whole should be highlighted, if existent. In this case, the a_{ij} coefficients for the distribution tier where i = import and j = G10, G11, are respectively 0.64 and 0.57 (cf.: table 4.15 and figure 4.6(b)). That means the nodes rely strongly on abroad: in particular, on average, for each euro of input that flows into the service center node, 78 cents come from abroad, while for each euro of input that flows into the stockists node, 74 cents come from abroad. This weaken the SCF solution proposed above, because casts shadows on the strength of the relationships between the two tiers within the supply chain. Is there that other analyses are needed, at the organizational level, to understand the extent of this importation phenomenon, and its importance on the possible SCF solution, and if such solution requires economies of scale in terms of organizations involved, if this number is achievable.

Manufacture of machinery for the food industry

This section provides the same output for the second supply chain, the manufacture of machinery for the food industry. The radar charts (cf.: section 3.4.3 at page 79) for this supply chain are presented in figure 4.9.

The rough data, that correspond to the arithmetic mean per node per measure, are summarized in table 4.21; the radar values ($x_{i,k,radar}$), again per node per measure, are summarized in table 4.22; as a way of example, the radar value "EBITDA" for the node "Manufacture of machinery for the food industry" (G6) is calculated as:

$$x_{6,EBITDA,radar} = \frac{x_{6,EBITDA} - x_{m,EBITDA}}{x_{M,EBITDA} - x_{m,EBITDA}} = \frac{414 - 206}{2005 - 206} = 0.12. \quad (4.3)$$

As already seen for the manufacture of tube supply chain, the four parameters are calculated using equation 3.15 on page 82, which values, per each node, are presented in table 4.20.

Node	F	E	P	N
G1	-0.17	0.18	-0.51	0.31
G2	0.12	0.12	-0.05	0.38
G3	0.17	0.43	-0.03	-0.29
G4	0.03	-0.43	-0.03	-0.36
G5	-0.13	-0.59	-0.25	-0.39
G6	-0.19	-0.23	-0.33	0.25
G7	0.38	0.29	0.01	0.17
G8	0.24	-0.21	0.38	-0.39
G9	0.33	0.33	-0.96	-0.31

Table 4.20: Values of the four parameters for the machinery for the food industry supply chain.

The matrix built from them is presented in figure 4.10(c): it is the overlap of the other two matrices reported in figure 4.10(a) and 4.10(b). As a way of example, the calculation of the parameter F for the node "Manufacture of machinery for the food industry" (G6) is:

$$g_F(\mathbf{x}_6) = \frac{\sum_{k\in F}(2 \cdot x_{6,k,radar} - 1) \cdot d_k}{3} = \\ = \frac{(2 \cdot 0.55 - 1) \cdot 1 + (2 \cdot 0.99 - 1) \cdot (-1) + (2 \cdot 0.35 - 1) \cdot (-1)}{3} = -0.19. \quad (4.4)$$

Node	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
G1	287.58	125.32	195.18	433.46	715.83	0.06	0.12	1.87	668.27	0.13	0.03	1.06
G2	260.76	113.73	195.6	514.93	997.64	0.05	0.14	1.15	1230.98	0.15	0.04	1
G3	278.91	118.33	224.07	683.7	1123.23	0.05	0.18	2.58	896.22	0.06	0.04	0.94
G4	248.1	142.22	240.66	135.04	256.57	0.05	0.19	2.9	489	0.11	0.04	1.02
G5	222.83	155.01	231.96	106.41	206.34	0.04	0.19	2.86	599.17	0.16	0.03	1.03
G6	286.31	127.47	196.13	262.67	413.78	0.05	0.16	1.78	78.05	0.23	0.03	1.08
G7	138.39	114.74	164.07	744.91	2005	0.02	0.05	1.84	3600.2	0.06	0.05	1.01
G8	225.92	124.86	218.21	291.25	605.55	0.05	0.19	2.68	950.99	0.09	0.04	0.95
G9	119.92	112.72	141.63	786.47	1516.03	0.03	0.13	1.82	4189	0.06	0.03	1.07

Table 4.21: Arithmetic means per measure per node.

Node	DOI	DOR	DOP	EBIT	EBITDA	ROS	FC/EBITDA	D/E	NFP	ΔTangA	DA/TA	AT
G1	1	0.3	0.54	0.48	0.28	1	0.47	0.41	0.14	0.44	0.16	0.87
G2	0.84	0.02	0.54	0.6	0.44	0.64	0.65	0	0.28	0.54	0.32	0.44
G3	0.95	0.13	0.83	0.85	0.51	0.79	0.93	0.82	0.2	0	0.46	0
G4	0.76	0.7	1	0.04	0.03	0.78	0.94	1	0.1	0.33	0.71	0.59
G5	0.61	1	0.91	0	0	0.62	0.98	0.97	0.13	0.57	0.19	0.64
G6	0.99	0.35	0.55	0.23	0.12	0.81	0.77	0.36	0	1	0	1
G7	0.11	0.05	0.23	0.94	1	0	0	0.39	0.86	0.04	1	0.53
G8	0.63	0.29	0.77	0.27	0.22	0.69	1	0.87	0.21	0.22	0.9	0.05
G9	0	0	0	1	0.73	0.26	0.59	0.38	1	0	0.03	0.97

Table 4.22: Radar axis values per measure per node.

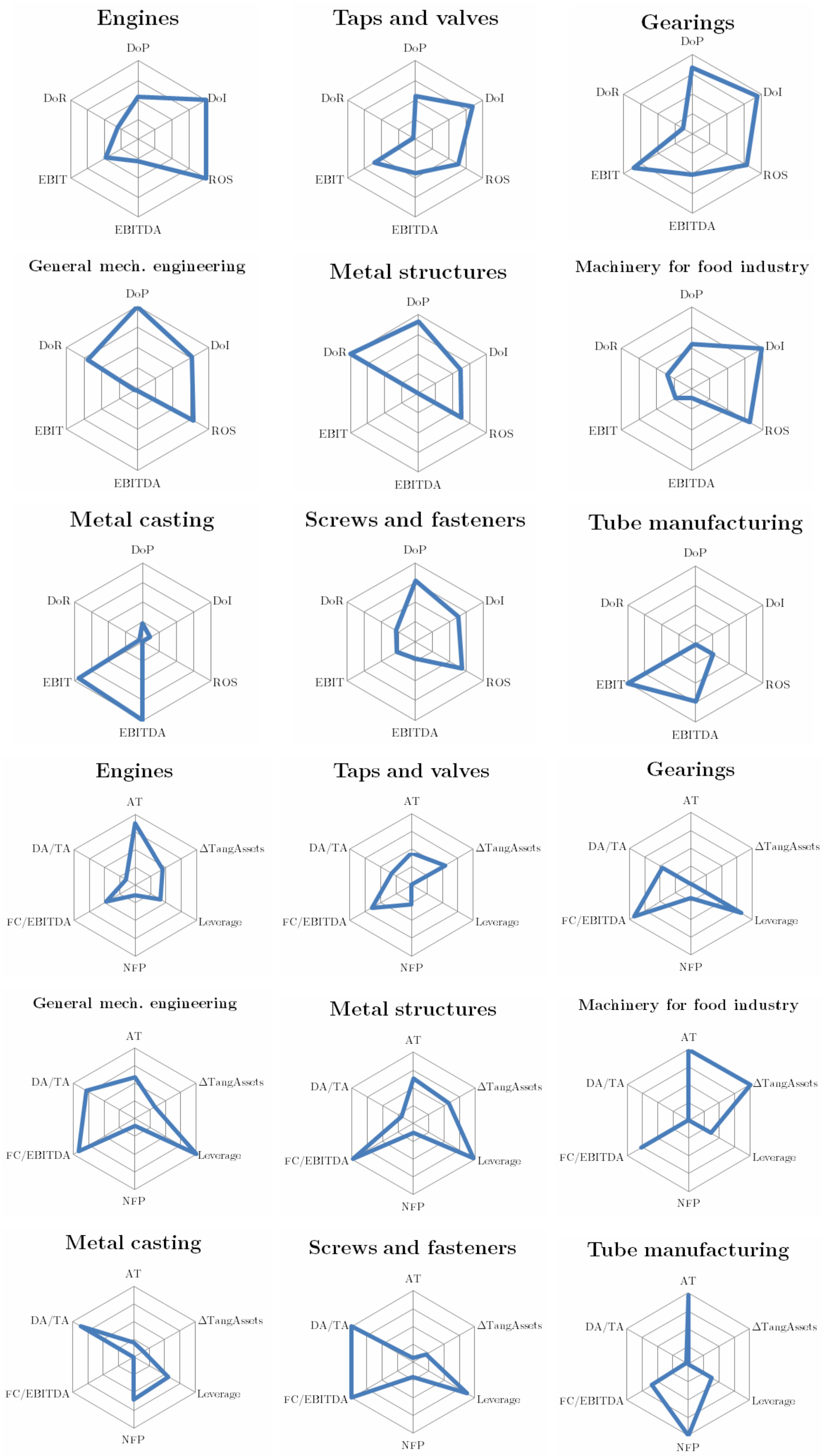
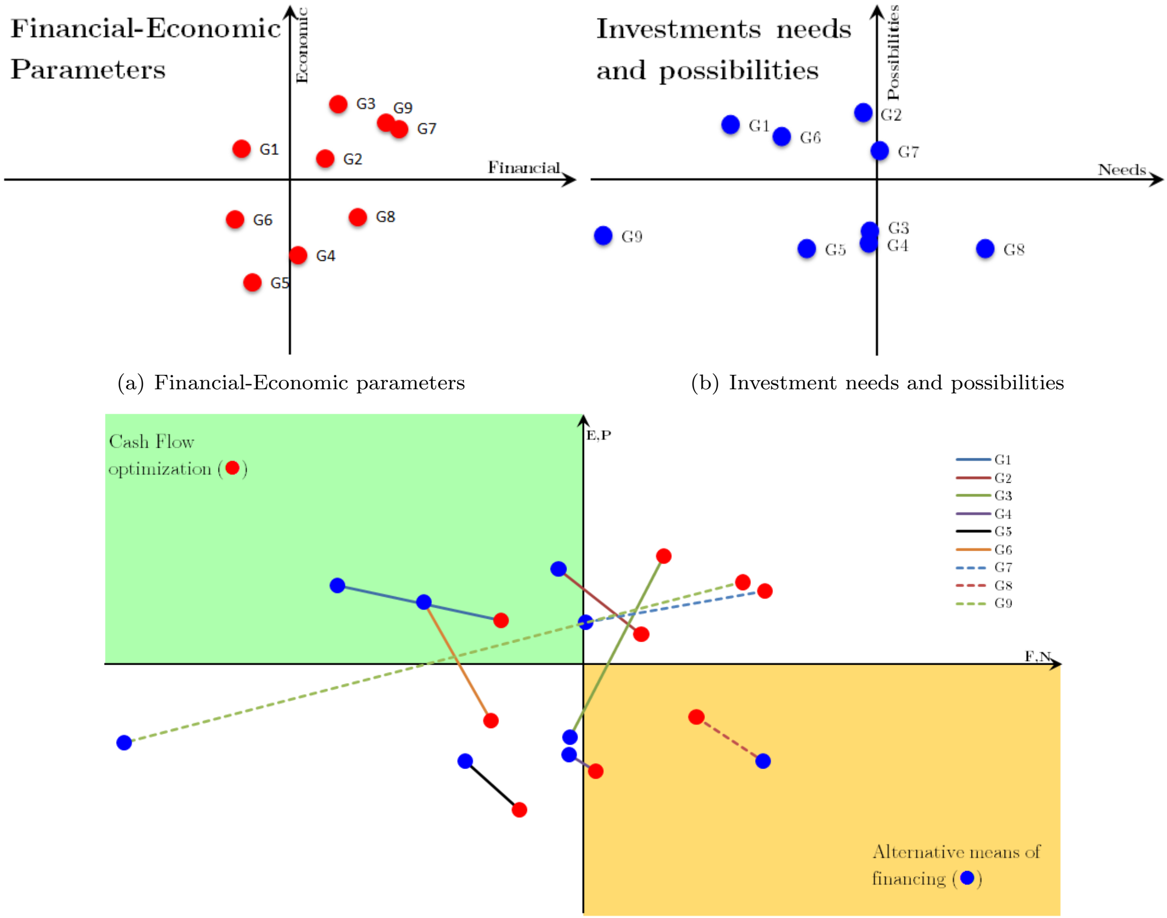


Figure 4.9: Radar charts for the machinery for the food industry supply chain.



(a) Financial-Economic parameters

(b) Investment needs and possibilities

(c) Financial assessment matrix

Figure 4.10: The financial assessment matrix and the two scatter plots from which it derives.

Considerations The belonging cluster for each of the nodes of the machinery for the food industry supply chain are reported in table 4.23.

Node		Parameters F	E	P	N		Cluster
G1	Engines	L	H	L	H	7	Cash flow optimization
G2	Taps and valves	H	H	L	H	2	Cash provider
G3	Gearings	H	H	L	L	4	Doubtful case
G4	General mechanical engineering	H	L	L	L	5	Low performer
G5	Metal structures	L	L	L	L	5	Low performer
G6	Machinery for the food industry	L	L	L	H	5	Low performer
G7	Metal casting	H	H	H	H	1	High performer
G8	Screws and fasteners	H	L	H	L	6	Possible AMF
G9	Manufacture of tubes	H	H	L	L	4	Doubtful case

Table 4.23: Belonging cluster for each node of the machinery for the food industry supply chain.

Different consideration can be drawn about those results:

- First of all, it should be noticed that the relative terms of this tool allows a node to be part of different clusters when analyzed in different supply chains: the node “Screws and fasteners” was in cluster "Low performer" in the previous analysis, while now it is in the cluster "Possible alternative means of financing". This is desirable: the purpose of the tool is to assess the supply chain, not the single node, therefore considerations about a node change, if the supply chain in which the node is inserted changes;

- The focus of this supply chain is clearly the node "manufacture of machinery for the food industry": it is characterized by the worst performance in terms of financial management of cash flow. This is probably due to the long production lead time needed by this node. A possible solution, that may increase also the economic performance, is an SCF program aimed at facilitate the financial management of cash flow for this node. Given the good performance in terms of receivables (cf.: figure 4.9(f), page 114), and the already mentioned long production lead time, that gives to this node the lowest CCC of the supply chain, such program should be focused on the supplier-side: a suitable program for this node might be a common SCF solutions that includes the decoupling of payable between firms belonging to the machinery for the food industry and their suppliers: the suppliers might collect a deflated value of the invoice after a reasonably short period of time, while the organizations in the manufacture of machinery for the food industry may receive an extension on the average payment terms, at least for an increase in the invoice nominal value. Note that such solutions would require the involvement of a financial institution;

- The metal casting node confirms itself as an high performer, despite the change of focus of the analysis. Its high performances make it the only node in the cluster "high performer";

- As can be seen in figure 4.10(b), the quadrant ($N > 0; P < 0$) contains a single point (G8). Relatively speaking, this means that nodes in this supply chain are able to match their needs for investment through canonical financing solutions, or do not present such needs. The presence of a single point in this cluster makes unlikely the possibility of applying set 2 SCF solutions (cf.: page 83) on a large scale. Solutions tailored on this specific node may be successful, but require an ad-hoc analysis;

Last, as for the manufacture of tube, it is important to consider the three output together: the low values of a_{ij} coefficients for the machinery for the food industry may put a limit to the application of an SCF solution. The involvement of suppliers is paramount to achieve an efficient application of such solutions: if the low level of the value of the exchanges between the focal node and its suppliers is reflected in an equally low strength of the corresponding relationships, the resulting SCF solution may be harder to be applied, due to a lack of involvement of suppliers. As already stated, this type of analysis is the first step, and requires other, organization-level, analyses.

Chapter 5

Conclusions

The conclusive chapter of this work summarizes the answers to the research questions, highlighting contextually the benefits of the model developed; thus, it recapitulates the outcome of the testing phase. After that, it analyzes the generalization process that decoupled the model from its empirical application, and presents the managerial implications of a correct, practical, utilization of the model. The chapter concludes with the suggested future researches.

5.1 Answers to the research questions

RQ 1. **The financial assessment of a supply chain**

- *What does it mean to financially assess a whole supply chain? How does this concept differs from the financial assessment of a single organization?*
- *What are possible choices of drivers that might suit the needs for the financial assessment of a supply chain?*

The model presents a choice of measure that, linked through apposite functions, are summarized in four parameters. The parameters are: Financial (F, ability to manage cash flow), Economic (E, ability to generate profit), Investment needs (N, necessity for capital), and Investment possibilities (P, possibility to increase debt through canonical financing solutions). These four parameters are estimated for each node of the supply chain, and together constitute the financial assessment of the node, in relation to the specific supply chain. This differs from other financial assessment methodology because the parameters are *relative*, i.e.: take into consideration the relationships between nodes in the supply chain. Therefore the financial assessment of a node depends on the entire supply chain, and not only on the node itself; this means that, even if the each node have a financial assessment, none of them can be evaluated without evaluating the whole supply chain. The financial assessment methodology is presented in sections 3.4.3.

As regards the model application, an example of the series of charts that compose the financial assessment for the supply chain object of this work is reported in figure 5.1. Such figure presents how the parameters F and E change from node to node. The usage of the radar chart allows to introduce that characteristics of relativity that makes the tool dependent from the whole supply chain.

RQ 2. **Financial assessment and supply chain profiling**

- *Are there more effective ways to represent a supply chain, in relation with its financial assessment?*
- *Is there a link between the representation methodology and the effectiveness of the financial assessment of a supply chain? Can a correct representation of a supply chain be part and parcel of its financial assessment?*

The representation methodology plays a crucial role in the financial assessment of the supply chain: as previously stated, the financial assessment of a single node depends on the supply chain as a whole, therefore a representation that improves the understanding of the relationships among the node can only increase the efficiency of the financial assessment itself. This model presents a representation methodology apt at highlight information about the structure of the supply chain that integrate and improve the quality of the messages that come out from the financial assessment. This makes the representation of the supply chain an integral part of its financial assessment: if the relationships among nodes are proven weak (and this message comes from the representation of the supply chain), the financial assessment is by definition weak as well, because it is based on the hypotheses that such links exists and are reasonably strong, applying the financial assessment to a couple of node that are weakly linked means to weaken the outcome, but this weakness is underlined by the supply chain representation. The representation methodology is presented in section 3.4.1 and 3.4.2.

A real-world example of how the supply chain representation tool is able to catch the structure and relationships of a supply chain is represented by the tube supply chain. Figure 5.2 shows the values of coefficient a_{ij}[1] for such supply chain; as it is possible to notice, on average, organizations in the distribution nodes rely three times more on importation of how much they do on national production; an accentuation of this behavior would have negatively affected the financial assessment as well. In fact, as previously stated, the considerations about each node *depend* on the whole supply chain, therefore if the supply chain represented is not correct (e.g.: because critical arcs results to carry a nearly null value), it may be that the considerations gathered downstream are incorrect as well. Moreover, the financial assessment outcome depends on how the supply chain is represented: even changing a single node may sensibly modify its outcome.

[1]Cf.: equation 3.2, page 75

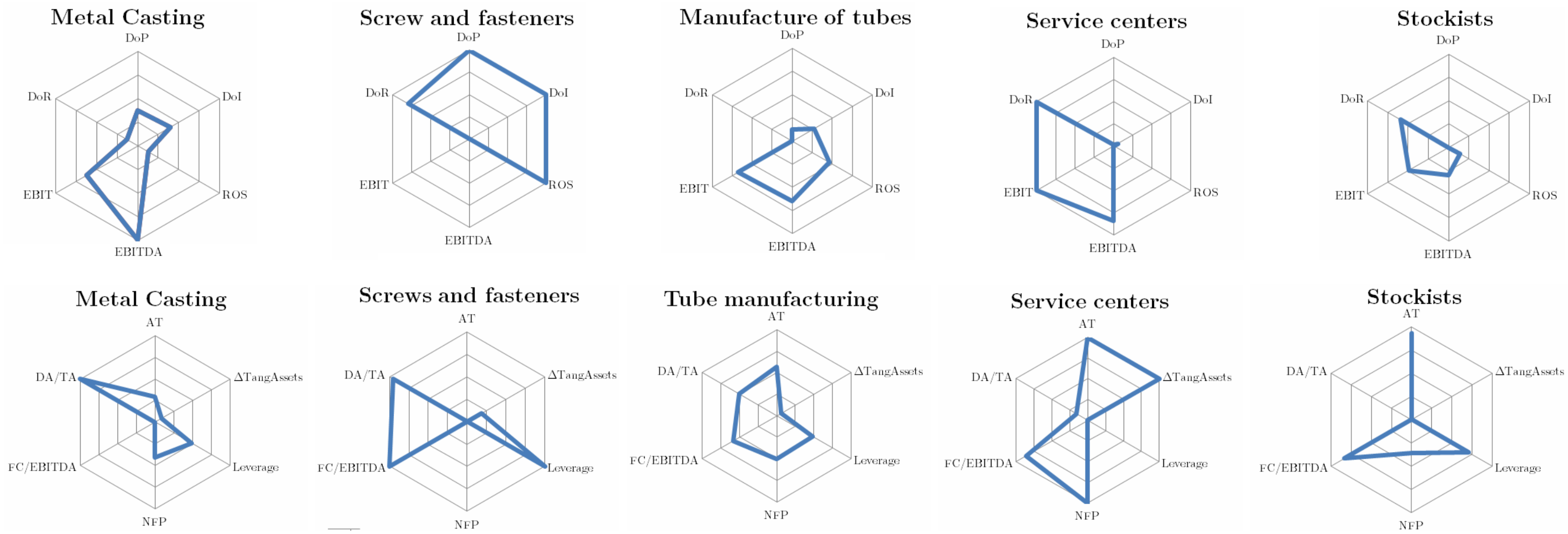


Figure 5.1: Radar charts for the tube manufacture supply chain.

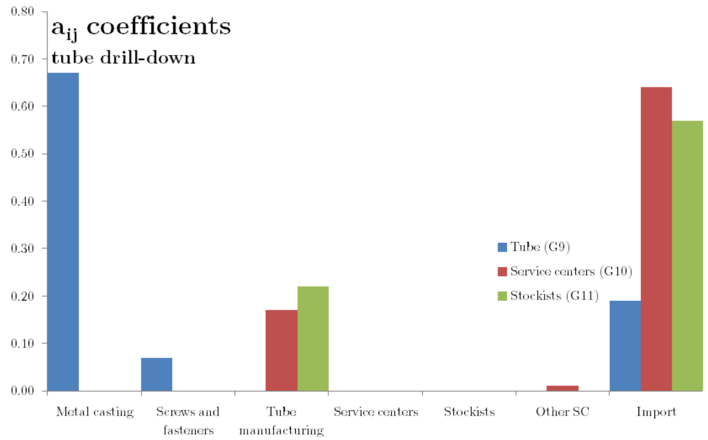


Figure 5.2: a_{ij} coefficients for the manufacture of tube supply chain.

RQ 3. **Financial assessment and supply chain finance**

- *Are there links between the financial assessment of a supply chain and an effective application of Supply Chain Finance solutions?*
- *How the different financial performance of supply chain nodes affects the implementation of Supply Chain Finance solutions?*

As anticipated, the outcome of the financial assessment methodology has been found to have links to the Supply Chain Finance topic. In particular, different combinations of the four parameters suggest that specific node may have different roles within in an SCF framework, and indicate nodes that present, on average, performances that can be improved through a non-canonical financing solution. As explained in section 3.2, this is quite important, because the correct implementation of an SCF solution is often based on the exploit of the supply chain links. Therefore, the first step of the analysis should always be at the supply chain-level; it is examining the supply chain as a whole that the correct consideration can be drawn: about the possibilities of reaching the correct level of economies of scale in terms of companies belonging to the nodes of the supply chain, but also about the gathering of information on strength and structure of relationships among nodes within the supply chain itself, information that may be relevant to the application of financing solution that needs particularly strong links to be effectively applied.

5.2 Consideration on the model testing

The application of the model presented in chapter four, carried out concurrently with its development, has been used also to test the model itself. The testing has been done gathering information and messages about the supply chain object of the work through analyses of secondary sources and interviews, and with an *a posteriori* confrontation of such messages with the ones provided by the model. Such test gave reasonably positive results, giving an indication, although not conclusive, about the consistency of the model.

In the specific, the manufacture of tube supply chain presented more characteristics that lend themselves to be tested. Among them:

- The best performer, as expected, is the metal casting node;
- The economical difficulties of the stockists, that are economically pressed by the upward tiers and find hard to produce positive performances, in relation to the other tiers, are confirmed;
- The better position respect to the stockists of the service centers, that exploit their capacity of extending the offer of the tube manufacturers, but are still pressed by the upward tiers. This difficulties are especially evident in the cash flow management of the service centers, and suggest how this tiers of the supply chain may benefit from a SCF solution apt to optimize the cash-to-cash cycle.

The machinery for the food industry supply chain gives, due to its nature, less immediate testable messages, but still provide useful information for the testing section; in particular, the relative (to the other node of the supply chain) lower needs for investment (especially in tangible assets) of the manufacture of machinery for the food industry are mirrored by the model, that puts the node in the lowest position as regards the parameter N.

5.3 Generalization

As already explained, the model application served as empirical basis for the model development: the current version of the model is the result of a process of generalization conducted in parallel to successive applications. The final application presented in chapter 4 is the result of the application of the generalized model.

Such process of generalization consisted in a progressive increase of the formality through which the model output has been developed, as well as the inclusion of rules, guidelines, and policy for the model application that are the result of a theoretical definition of possible application scenario, rather than the outcome of the application presented in chapter 4. Examples of the results of such process of generalization can be the ontology defined at page 68, that contains components that have not been used in the application of the model, or, in a simpler way, the clustering process (cf.: 85), that take into consideration all the possible alternatives, and not only the ones sprang out from the model application. The comparison between a first representation of the manufacture of tube supply chain and the one presented in chapter 4 is reported in figure 5.3.

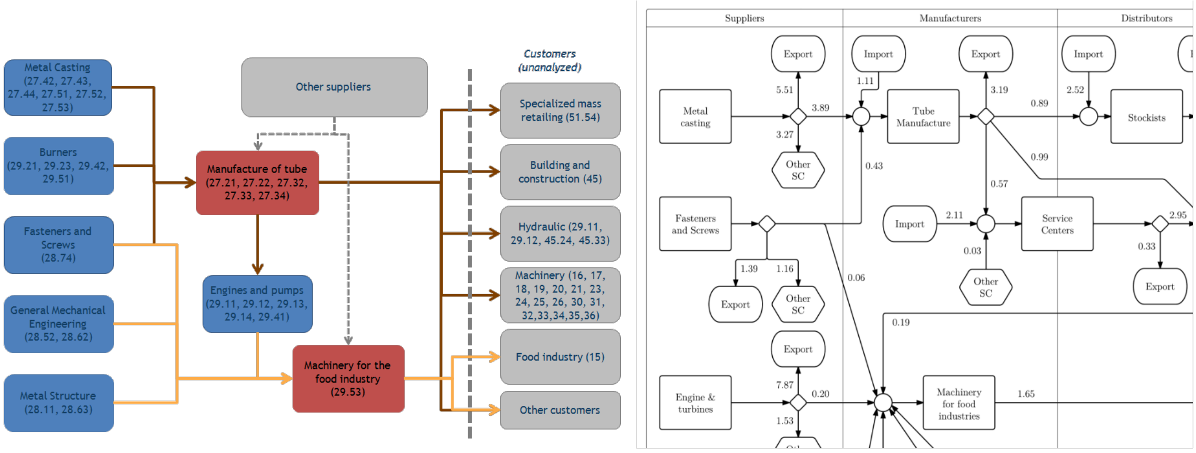


Figure 5.3: A first attempt of the Supply Chain Flowchart compared to the final version (part of).

5.4 Managerial implications

In addition to the theoretical contribution of this work, it presents also different managerial implications. The prototype developed from the model shows how it can be used, by a generic user, for practically represent and financially assess a supply chain; it shows also how is possible to automate the clustering process that links the model outputs to the application of SCF solutions to the supply chain. The possibility of automate the application of the model highlights its managerial implications.

First of all, the model could be useful for banks and financial institution willing to inquire the possible application of an SCF solution to a supply chain. As specified in section 3.2.1 at page 67, this model presents the first high-level, unavoidable, analysis necessary for the effective application of SCF solutions to a supply chain. Further analyses, at the organizational level, are necessary, but not sufficient. SCF solutions often base their effectiveness on the exploitation of supply chain links and relationships, as well as on a sufficiently high number of organizations involved. For this reason it is important for a generic financial institution, to begin the necessary analyses from the supply chain as a whole.

Second, the model finds an application also on industry and supply chain associations. Often the purpose of such associations is to monitor, lead, and predict the development of their own supply chain (or industry). This includes also economical and financial analyses, like in the case of the Italian *Siderweb*[2], that provides economical analysis related to the industry of interest on a more-than-yearly basis. For this association, assess financially their own supply chain may be critical, especially in times of economic downturn, when a correct understand of the potentiality of the nodes, and of the benefits that an SCF solution may bring to an entire supply chain is critical.

Ultimately, the model shows interesting managerial implications also for single organizations. The concept of supply chain visibility, and in general of the sharing of useful information among partners, is critical in the complex nowadays supply chains (Caridi et al. [2010]). A correct financial assessment of the whole supply chain, as well as a correct understanding of the messages regarding the application of SCF solutions, represent a great opportunity for organizations within a supply chain to improve their visibility on other nodes, with mutual benefits. Having visibility on the financial assessment of the nodes up- and downstream in relation to the whole supply chain will help organizations in promoting actively the application of SCF solutions to the supply chain: such behavior is quite critical for all those solutions

[2]Industry association for the Italian metallurgy.

that do not require the presence of a proposing third part, as well as all those solution that required to be activated by one of the company involved.

5.5 Future research

Future research on the topic of this thesis can further investigate a different number of aspects. In particular, expected future development can be classified as:

- Modification of the model structure and further validations:
  - The model can be applied to other supply chain, for example to non-manufacturing supply chain, to extend the testing process started in this work. Such additional tests will refine the generalization process, and completely decouple the model from the empirical bases on which it is linked in this thesis;
  - Different sets of indicators can be tested: as noticed, the selection of the indicators is somehow partially subjective. A work focused on the testing of different sets of indicators and on the analysis of their benefits and shortcomings can be highly beneficial for the model.
  - In relation to the previous point, a future development might modify the model structure in order to untied it from the balance sheet data on which it is linked now, in order to provide an improved version of the model that contains future-oriented, as well as non-financial, indicators.
- Modification of the model structure related to further research in the topic of Supply Chain Finance:
  - The model can be further developed to include a more detailed characterization of solutions of SCF. In particular, it can be modify to include less-known solutions of supply chain finance, as well as new ones, still to be developed. This development of the model can affect the clustering process (i.e.: expand or review the number of clusters from the actual nine), and/or the structure of the model itself (expand or review the meaning and structure of the four parameter F, E, P, and N at the base of the financial assessment);
  - The model can be further developed to include a tailored assessment of the benefits of SCF solutions on the specific supply chain. In particular, such development should be placed after the clustering process, and should quantitatively assess how and in which terms an SCF solution could improve the economic and financial conditions of the organizations within the nodes;
  - The model should be expanded to include the whole set of analysis at the organizational-level required for the effective application of SCF solution to a supply chain.
- Another sets of improvements is related to the inquiring of the interactions between the present model, the topic of Information and Communications Technology (ICT), and the one of SCF: a correct understanding of the correct technologies to support the solutions of SCF is critical for the supply chain understanding that is at the base of this model. For example, understand the role and the characteristics that a system of ePayable might have within an SCF framework would be easily inserted in this model, because it would represent an enabling condition that would facilitate (or obstacle, if missing) the application of SCF solutions;
- A last set of future improvements is related to the field of computer science: the prototype of a tool based on the present model, presented in section 3.5 at page 88, could be improved. In fact, it could be transformed in a complete software for the financial assessment of the supply chain. Such software would have strong managerial applications but, by all means, shall not substitute the required understanding of the supply chain, necessary for a comprehensive evaluation of the application of SCF solutions to the supply chain.

Ultimately, should be noticed that further applications of the model, together with other expected improvement of the present work, would be beneficial not only for the model itself, but also for broader topics: for example, it would provide the real-world data that are deemed necessary for the progress in the field of Supply Chain Finance (Pfohl and Gomm [2009]).

List of Abbreviations

List of all the abbreviations used in this work.

Acronym	Extended
CCC	Cash to Cash Cycle
COGS	Cost of goods sold
e-SCM	e-Supply Chain Management
ER model	Entity-Relationship model
ICT	Information and Communications Technology
LSP	Logistics Service Provider
NOI	Net Operating Income
OWC	Operating Working Capital
OWL	Web Ontology Language
SC	Supply Chain
SCC	Supply Chain Council
SCF	Supply Chain Finance
SCM	Supply Chain Management
SCR	Supply Chain Representation
SSCM	Sustainable Supply Chain Management
TA	Total Assets
WACC	Weighted Average Cost of Capital
XML	eXtensible Markup Language

Appendix A

Qualitative data: the case studies

In this appendix are presented the set of case studies composing the qualitative database for the model application. These qualitative data constitute a part of the supply chain understanding necessary for the model application. These case studies have been developed through interviews to practitioners belonging to the part of the Italian mechanical supply chain object of this work. The body of knowledge constituted by the interviews is divided into two parts.

A.1 First set of interviews

The first part is based on the question structure reported in table A.1.

No.	Question
1	No. firms in the industry
2	Average production lead time
3	Production modality
4	Seasonality
5	Purchasing markets
6	Purchasing currency
7	Sales markets
8	Sales currency
9	Percentage of raw materials on revenues[1]
10	Percentage of direct labor on revenues[1]
11	Other significant factors that affect COGS
12	Average invoicing period
13	Average receivables period
14	Average payable period
15	Asset growth level
16	Major needs for investments
17	Existence of particular taxation or regulation
18	Digital level of business documents exchange

[1] Values included as mean of cross-control among bodies of knowledge.

Table A.1: Questionnaire for the first set of interviews

The case studies are reported as follows in table A.2.

Firm name	FAVA SPA	TECHNOGEL SPA	VELATI SRL
Date	40920	40921	40924
ATECO code	2953	2953	2953
Q1	6	15 Italy, 80 ROW	10
Q2	7/8 months	1 month stocked, 2 to 4 other prd	2/3 months
Q3	MTO	MTS (70% units; 50% value); MTO, ATO	MTO 90%; MTS 10%
Q4	3 to 4 years	Summer, lowered by global market	None
Q5	Italy, France	Italy and Switzerland	Italia
Q6	Euro	Euro + other currency	Euro
Q7	Global	Global	60% estero, 40% italia
Q8	Euro	Euro and USD	Euro e USD
Q9	Coherent	Coherent	Coherent
Q10	Coherent	Coherent	Coherent
Q11	dn/da	dn/da	dn/da
Q12	dn/da	dn/da	dn/da
Q13	60 days	10 to 60 days	180 days in Italy, 0 abroad
Q14	dn/da	dn/da	dn/da
Q15	dn/da	dn/da	dn/da
Q16	dn/da	Every 2 to 3 years	dn/da
Q17	None	None	None
Q18	Low (only email)	Low (only email)	Low (only email)

Firm name	VELO	WCB Icecream	Cavanna
Date	40924	40931	40931
ATECO code	2953	2953	dn/da
Q1	10	3	dn/da
Q2	3 months	2 months	6 months
Q3	MTO 50%; MTS 50%	MTO 50%; MTS 50%	ETO 95%; MTS 5%
Q4	None	Summer, lowered by global market	None
Q5	Globale	Italy and China	dn/da
Q6	Euro	Euro	dn/da
Q7	Globale	Globale	95% Abroad; 5% Italy
Q8	Euro, USD	Euro (scelta)	Euro, USD, Brasilian Real
Q9	Coherent	Coherent	Coherent
Q10	Coherent	Coherent	Coherent
Q11	dn/da	dn/da	dn/da

Q12	dn/da	dn/da	dn/da	
Q13	120 days Italy, 0 abroad	60 days Italy, 0 abroad	0 days	
Q14	dn/da	dn/da	dn/da	
Q15	dn/da	dn/da	dn/da	
Q16	dn/da	Every 6 years	In R&D, not in tangible assets	
Q17	None	None	None	
Q18	Low (only email)	Low (only email)	dn/da	

Firm name	Giorgi Tubi Flessibili	ECOLINE	CASCHERA PROFILATI - S.R.L.	Cena Fittings
Date	40931	40931	40931	40931
ATECO code	2732	2722	2732	dn/da
Q1	dn/da	dn/da	dn/da	dn/da
Q2	7/10 days	10 days	15 days	3 months
Q3	MTO	50% MTS; 50% MTO	MTO	MTS 40%; MTO 60%
Q4	dn/da	Summer	None	Peak pre-closure
Q5	Italy, China	Italy, North Europe	Italy, Europe	Italy, ROW
Q6	Euro e USD	Euro	Euro	Euro
Q7	Global	Italia	Italia	Europe, USA, Asia
Q8	Euro	Euro	Euro	Euro, USD
Q9	Coherent	Coherent	Coherent	Coherent
Q10	Coherent	Coherent	Coherent	Coherent
Q11	dn/da	dn/da	dn/da	dn/da
Q12	dn/da	dn/da	dn/da	dn/da
Q13	30 days	90 to 120 days	60 to 90, peak 180 days	dn/da
Q14	dn/da	dn/da	dn/da	dn/da
Q15	dn/da	dn/da	dn/da	dn/da
Q16	dn/da	Not machinery	Maintenance, photovoltaic systems	dn/da
Q17	None	None	dn/da	dn/da
Q18	Low (email)	Warehouse visibility for customers	dn/da	dn/da

Table A.2: Results of the first set of interviews

A.2 Second set of interviews

The second set of interviews was focused at the estimation of a number of arc values in the supply chain flowchart of the tube supply chain. To do so, some interview with practitioners has been carried out, with a much more practical point of view respect to the first set. The questionnaire used is reported in table A.3.

No.	Question
1	Declared category: service center or stockist
2	Importation on total purchases
3	Exportation on total purchases
4	Purchases items apart from main products[1]
5	Main cost item in income statement
6	Use of additional tier of distributors (% on value of product sold)

[1] What the firm buys apart from distributed product: raw or indirect materials, sub-components, and so on.

Table A.3: Questionnaire for the second set of interviews

The interview results are reported in table A.4.

Firm name	Ferro Tubi Lamiere Rossi	Giacomello tubi e lamiere spa	Centro servizi inox	Fratelli Pelandi Srl
Date	11/06/2012	11/06/2012	11/06/2012	11/06/2012
Q1	Stockist	Stockist	Service center	dn/da
Q2	0	50	90	100
Q3	0	40	20	0
Q4	None	None	None	None
Q5	Goods to be distributed	Goods to be distributed	Goods to be distributed	Goods to be distributed
Q5	Direct	Direct	20% Distribution tier 80% Direct	Direct

Firm name	Area Inox SRL	Acerinox Italia	Acroni Italia	Caprin SPA
Date	11/06/2012	11/06/2012	11/06/2012	11/06/2012
Q1	Stockist	Service center	Service center	Stockist
Q2	5	100	40	5
Q3	10	10	dn/da	0
Q4	None	None	Metal wreckage	None
Q5	Goods to be distributed	Goods to be distributed	Goods to be distributed	Goods to be distributed
Q5	10% Distribution tier 90% Direct	Direct	Direct	Direct

Table A.4: Results of the second set of interviews.

Appendix B

Attributes included in $\mathcal{D}$

This appendix contains the complete list of attributes downloaded from the Aida on-line database, plus the indicators manually calculated and added to the dataset; the whole set of attributes constitutes the database $\mathcal{D}$ (cf.: section 2.2.3, page 56).

The legend for table B.2 is provided in table B.1

Code	Description
A	The variable has been Added to the initial database
D (Source)	The variable was present in the Downloaded database
D (Type)	The variable is of Discrete type
N	The variable is of Nominal type
O	The variable is of Ordinal type
C	The variable is of Continuous type

Table B.1: Legend of table B.2

Name	Source	Type	Units
ID (progressive)	A	D	
Name	D	N	
Year of Constitution	D	D	
Address	D	N	
Postal Code	D	O	
City	D	N	
Province	D	N	
Region	D	N	
Year of last balance sheet available	D	D	
Employees	D	D	
CCIAA number	D	O	
Total Receivables Due From Shareholders	D	C	['000] €
Called share capital	D	C	['000] €
Total Fixed Assets	D	C	['000] €
Total Intangible Fixed Assets	D	C	['000] €
Start-up and expansion costs	D	C	['000] €
Research and dev. exp.	D	C	['000] €
Ind. patents and intellect. property rights	D	C	['000] €
Concessions, licenses, trademarks and similar rights	D	C	['000] €
Goodwill	D	C	['000] €
Additions in progress and advances	D	C	['000] €
Others	D	C	['000] €
(Amortization provision)	D	C	['000] €

Name	Source	Type	Units
Total Tangible Fixed Assets	D	C	['000] €
Land And Buildings	D	C	['000] €
Plant And Machinery	D	C	['000] €
Indust. And Commercial Equipment	D	C	['000] €
Other Assets	D	C	['000] €
Additions In Progress And Advances	D	C	['000] €
(Depreciation Provision)	D	C	['000] €
Total Financial Fixed Assets	D	C	['000] €
Total Equity Investments	D	C	['000] €
Subsidiary companies	D	C	['000] €
Associated companies	D	C	['000] €
Parent companies	D	C	['000] €
Other companies	D	C	['000] €
Total Receivables	D	C	['000] €
Due from subsidiary comp.	D	C	['000] €
Due from subs. comp. - beyond 12 months	D	C	['000] €
Due from assoc. comp.	D	C	['000] €
Due from assoc. comp. - beyond 12 months	D	C	['000] €
Due from parent comp.	D	C	['000] €
Due from parent comp. - beyond 12 months	D	C	['000] €
Due from other comp.	D	C	['000] €
Due from other comp. - beyond 12 months	D	C	['000] €
FINANCIAL RECEIV. WITHIN 12 MONTHS	D	C	['000] €
FINANCIAL RECEIV. BEYOND 12 MONTHS	D	C	['000] €
Other securities	D	C	['000] €
Own shares	D	C	['000] €
Own shares: par value	D	C	['000] €
Total Current Assets	D	C	['000] €
Total Inventories	D	C	['000] €
Raw And Consumable Materials	D	C	['000] €
Work In Progress And Semifinished Products	D	C	['000] €
Contract Work In Progress	D	C	['000] €
Finished Products And Goods	D	C	['000] €
Advances	D	C	['000] €
Total Receivables	D	C	['000] €
Trade accounts	D	C	['000] €
Trade accounts - beyond 12 months	D	C	['000] €
Due from subs. comp.	D	C	['000] €
Due from subs. comp. - beyond 12 months	D	C	['000] €
Due from assoc. comp.	D	C	['000] €
Due from assoc. comp. - beyond 12 months	D	C	['000] €
Due from parent comp.	D	C	['000] €
Due from parent comp. - beyond 12 months	D	C	['000] €
Tax receivables	D	C	['000] €
Tax receiv. - beyond 12 months	D	C	['000] €
Tax receiv. for prepaid taxes	D	C	['000] €
Tax receiv. for prepaid taxes - beyond 12 months	D	C	['000] €
Receiv. due from others	D	C	['000] €
Receiv. due from others - beyond 12 months	D	C	['000] €
RECEIV. DUE WITHIN 12 MONTHS	D	C	['000] €
RECEIV. DUE BEYOND 12 MONTHS	D	C	['000] €
Total Financial Assets	D	C	['000] €
Invest. In Subs. Comp.	D	C	['000] €
Invest. In Assoc. Comp.	D	C	['000] €

Name	Source	Type	Units
Invest. In Parent Comp.	D	C	['000] €
Other Investments	D	C	['000] €
Own shares	D	C	['000] €
Own shares: par value	D	C	['000] €
Other securities	D	C	['000] €
Total Liquid Funds	D	C	['000] €
Bank And Postal Deposits	D	C	['000] €
Checks	D	C	['000] €
Cash And Cash Equivalents	D	C	['000] €
Total Accrued Income And Prepaid Expenses	D	C	['000] €
Accrued income and prepaid exp.	D	C	['000] €
Total Assets	D	C	['000] €
Shareholders' Funds	D	C	['000] €
Capital Stock	D	C	['000] €
Share Premium Reserve	D	C	['000] €
Revaluation Reserves	D	C	['000] €
Legal Reserve	D	C	['000] €
Statutory Reserves	D	C	['000] €
Reserve For Treasury Stock	D	C	['000] €
Other Reserves	D	C	['000] €
GROUP consolidation reserve	D	C	['000] €
Retained Earnings (Losses)	D	C	['000] €
Profit (Loss) For The Year	D	C	['000] €
Group Capital Stock And Reserves	D	C	['000] €
Minority Interests In Cap. And Reserves	D	C	['000] €
Minority Interests In Profit (Loss) For The Year	D	C	['000] €
Minority Interests Shareholders' Funds	D	C	['000] €
Total Provisions For Risks And Charges	D	C	['000] €
Employee Pensions And Similar Obligations	D	C	['000] €
Taxation (Including Deferred Taxation)	D	C	['000] €
Other Provisions	D	C	['000] €
Consolidation Provision	D	C	['000] €
Severance Indemnity Reserve	D	C	['000] €
Total Payables	D	C	['000] €
Bonds	D	C	['000] €
Bonds beyond 12 months	D	C	['000] €
Convertible bonds	D	C	['000] €
Convertible bonds - beyond 12 months	D	C	['000] €
Due to shareholders for loans	D	C	['000] €
Due to shareholders for loans - beyond 12 months	D	C	['000] €
Due to banks	D	C	['000] €
Due to banks - beyond 12 months	D	C	['000] €
Due to other lenders	D	C	['000] €
Due to other lenders - beyond 12 months	D	C	['000] €
Advances	D	C	['000] €
Advances - beyond 12 months	D	C	['000] €
Due to suppliers	D	C	['000] €
Due to suppliers - beyond 12 months	D	C	['000] €
Negotiable instruments	D	C	['000] €
Negotiable instruments - beyond 12 months	D	C	['000] €
Due to subsidiary companies	D	C	['000] €
Due to subsidiary companies - beyond 12 months	D	C	['000] €
Due to associated companies	D	C	['000] €
Due to associated companies -beyond 12 months	D	C	['000] €

Name	Source	Type	Units
Due to parent companies	D	C	['000] €
Due to parent companies beyond 12 months	D	C	['000] €
Tax payable	D	C	['000] €
Tax payable beyond 12 months	D	C	['000] €
Due to social security institutions	D	C	['000] €
Due to social security institutions - beyond 12 months	D	C	['000] €
Other payables	D	C	['000] €
Other payables beyond 12 months	D	C	['000] €
Payables due within 12 months	D	C	['000] €
Payables due beyond 12 months	D	C	['000] €
TOTAL ACCRUED EXPENSES AND DEFERRED INCOME	D	C	['000] €
Fees on loans	D	C	['000] €
Total Liabilities And Shareholders' Funds	D	C	['000] €
TOTAL MEMORANDUM ACCOUNTS	D	C	['000] €
TOTAL WARRANTIES SUPPLIED	D	C	['000] €
TOTAL VALUE OF PRODUCTION	D	C	['000] €
Revenues from sales and services	D	C	['000] €
Changes in inventories	D	C	['000] €
Changes In Contract Work In Progress	D	C	['000] €
Total Changes	D	C	['000] €
Additions to fixed assets	D	C	['000] €
Other Revenue	D	C	['000] €
operating grants	D	C	['000] €
Total Production Costs	D	C	['000] €
Raw, consum. mat. and goods for resale	D	C	['000] €
Services	D	C	['000] €
Use Of Third Parties Assets	D	C	['000] €
Total personnel costs	D	C	['000] €
Wages and salaries	D	C	['000] €
Social Security Charges	D	C	['000] €
Severance indemnities	D	C	['000] €
Pensions and similar obligations	D	C	['000] €
Other Costs	D	C	['000] €
Severance Indemnity + Pension + Other Costs	D	C	['000] €
Total depreciation, amortization and writedowns	D	C	['000] €
Amort. of intangible fixed assets	D	C	['000] €
Depr. of tangible fixed assets	D	C	['000] €
Writedown of fixed assets	D	C	['000] €
Depreciation, amortization and writedowns of fixed assets	D	C	['000] €
Writedown of receivables	D	C	['000] €
Change In Inventory Of Raw And Consumable Materials	D	C	['000] €
Provisions Fo Risks And Charges	D	C	['000] €
Other Provisions	D	C	['000] €
Other Operating Expenses	D	C	['000] €
Operating Margin	D	C	['000] €
Added Value	D	C	['000] €
Total Financial Income And Charges	D	C	['000] €
Total income from equity investments	D	C	['000] €
Subsidiaries/Associated comp.	D	C	['000] €
Total Other Financial Income	D	C	['000] €
From financial receivables	D	C	['000] €
Subs. and assoc. Comp.	D	C	['000] €
From securities held as fixed assets	D	C	['000] €
From securities held as current assets	D	C	['000] €

Name	Source	Type	Units
From Securities	D	C	['000] €
Income other than the above	D	C	['000] €
Income other than the above (subsidiaries and associates companies)	D	C	['000] €
Total Financial Charges	D	C	['000] €
Financial Charges from financial receivables Subs. and assoc.	D	C	['000] €
Profit And Loss On Foreign Exchange	D	C	['000] €
Total Financial Assets Adjustments	D	C	['000] €
Total Revaluations	D	C	['000] €
Reval. of equity investments	D	C	['000] €
Reval. of other financial assets	D	C	['000] €
Reval. of securities	D	C	['000] €
Total Writedowns	D	C	['000] €
Writedowns of equity invest.	D	C	['000] €
Writedowns of other fin. Ass.	D	C	['000] €
Writedowns of securities	D	C	['000] €
Total Extraordinary Revenues And Charges	D	C	['000] €
Extraordinary Revenues	D	C	['000] €
Capital gains	D	C	['000] €
Extraordinary Charges	D	C	['000] €
Capital losses	D	C	['000] €
Taxes previous period	D	C	['000] €
Profit/Loss Before Taxation	D	C	['000] €
Total Current, Deferred And Prepaid Income Taxes	D	C	['000] €
Current Taxes	D	C	['000] €
Prepaid And Deferred Taxes	D	C	['000] €
Profit (Loss)	D	C	['000] €
Profit (Loss) Third Parties	D	C	['000] €
Profit (Loss) Group	D	C	['000] €
ATECO (2007 codification)	D	O	
Status of the firm	D	N	
Liquidity Ratio	D	C	a.v.
Current Ratio	D	C	a.v.
Current Liabilities/Tot Ass.	D	C	a.v.
Long/Med Term Liab/Tot Ass.	D	C	a.v.
Tang. Fixed Ass./Share Funds	D	C	a.v.
Leverage	D	C	a.v.
Coverage Of Fixed Assets	D	C	a.v.
Banks/Turnover (%)	D	C	a.v.
Cost Of Debit (%)	D	C	a.v.
Solvency Ratio (%)	D	C	a.v.
Share Funds/Liabilities	D	C	a.v.
Net Financial Position	D	C	a.v.
Debt/Equity Ratio	D	C	a.v.
Working Cap. Turnover (Times)	D	C	a.v.
Stocks/Turnover (Days)	D	C	days
Stocks/Cost Goods Sold (Days)	D	C	days
Days of receivables	D	C	days
Days of payables	D	C	days
Cash-to-cash cycle	D	C	days
Ebitda	D	C	['000] €
Return On Asset (Roa) (%)	D	C	a.v.
Return On Investment (Roi) (%)	D	C	a.v.
Return On Sales (Ros) (%)	D	C	a.v.
Return On Equity (Roe) (%)	D	C	a.v.

Name	Source	Type	Units
Net P/L / Operating P/L (%)	D	C	a.v.
Net Working Capital	D	C	['000] €
Gross Profit	D	C	['000] €
Cash Flow (proxy)	D	C	['000] €
Plant And Machinery (t-1)	D	C	['000] €
Indust. And Commercial Equipment (t-1)	D	C	['000] €
Raw And Consumable Materials (t-1)	D	C	['000] €
Work In Progress And Semifinished Products (t-1)	D	C	['000] €
Finished Products And Goods (t-1)	D	C	['000] €
Trade accounts (t-1)	D	C	['000] €
Trade accounts - beyond 12 months (t-1)	D	C	['000] €
Due to suppliers (t-1)	D	C	['000] €
Due to suppliers - beyond 12 months (t-1)	D	C	['000] €
Total Tangible Fixed Assets (t-1)	D	C	['000] €
Raw Materials on revenues	A	C	a.v.
Wages and salaries on revenues	A	C	a.v.
Needs of the business cycle (method 1)	A	C	['000] €
Needs of the business cycle (method 2)	A	C	['000] €
Variation in Fixed Tangible Assets	A	C	a.v.
Debts vs. banks on EBITDA	A	C	a.v.
Financial Charges on revenues	A	C	a.v.
EBITDA on financial charges	A	C	a.v.
Net Financial Position on EBITDA	A	C	a.v.
Net Financial Position on Equity	A	C	a.v.

Table B.2: Attributes in database $\mathcal{D}$

Appendix C

Geographic maps of industry concentration

This appendix provides the geographical maps of industry concentration in Italy for the part of the mechanical industry object of this work.

C.1 Map data

A summary of the data represented in the maps are reported in table C.1.

Reference Group	Total	Max no. in a province	Average	Median
1	770	90	6.9	3
2	485	120	4.4	0
3	341	47	3.1	0
4	8078	594	72.8	31
5	4900	297	44.1	26
6	833	118	7.5	2
7	487	80	4.4	2
8	410	71	3.7	0
9	351	46	3.2	1
10	75	12	0.7	0
11	178	35	1.6	0

Table C.1: Summary of the data used to compile the maps.

C.2 Map design

To design the maps, a color model has been used. A color has been assigned to each province, based on the number of firms present in the province. To select the right color per province, three color has been fixed for each map (using the RBG terminology):

- Green (0;255;0): the province contains no firm of the specific group;
- Yellow (255;255;0): the province contains exactly the average number of firms for the specific group;
- Red (255;0;0): the province contains the maximum number of firms for the specific group.

Colors for provinces that do not fall in any of the three categories are chosen automatically based on the number of firms in the province. This color model allows to have the range of colors from red to green mirroring the distribution of firms in the province, that is strongly asymmetric. An example that can clarify this point is presented in figure C.1.

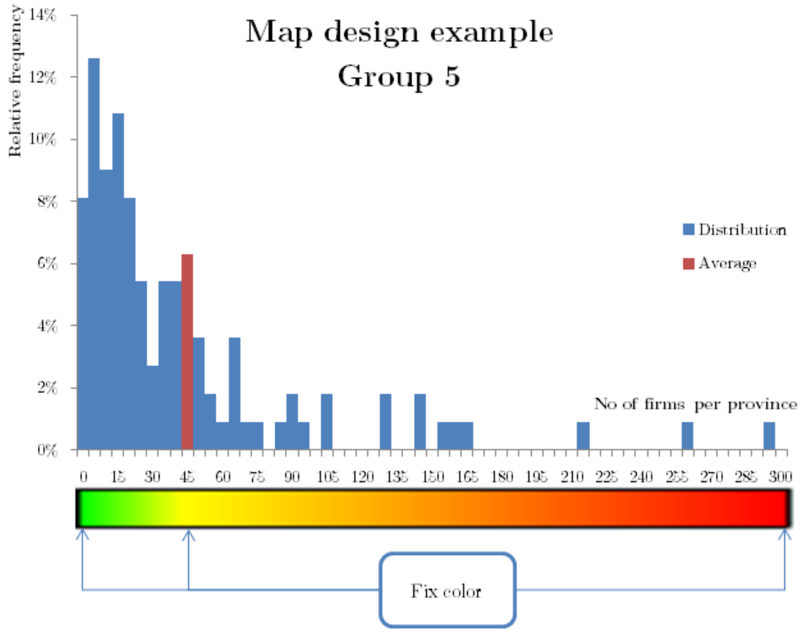


Figure C.1: An example of map construction.

C.3 Maps

Each map is provided with its scale of colors, with the indication of the average value, calculated as percentage of the maximum value (where the maximum value is the no of firms in the province with the highest concentration, per each reference group).

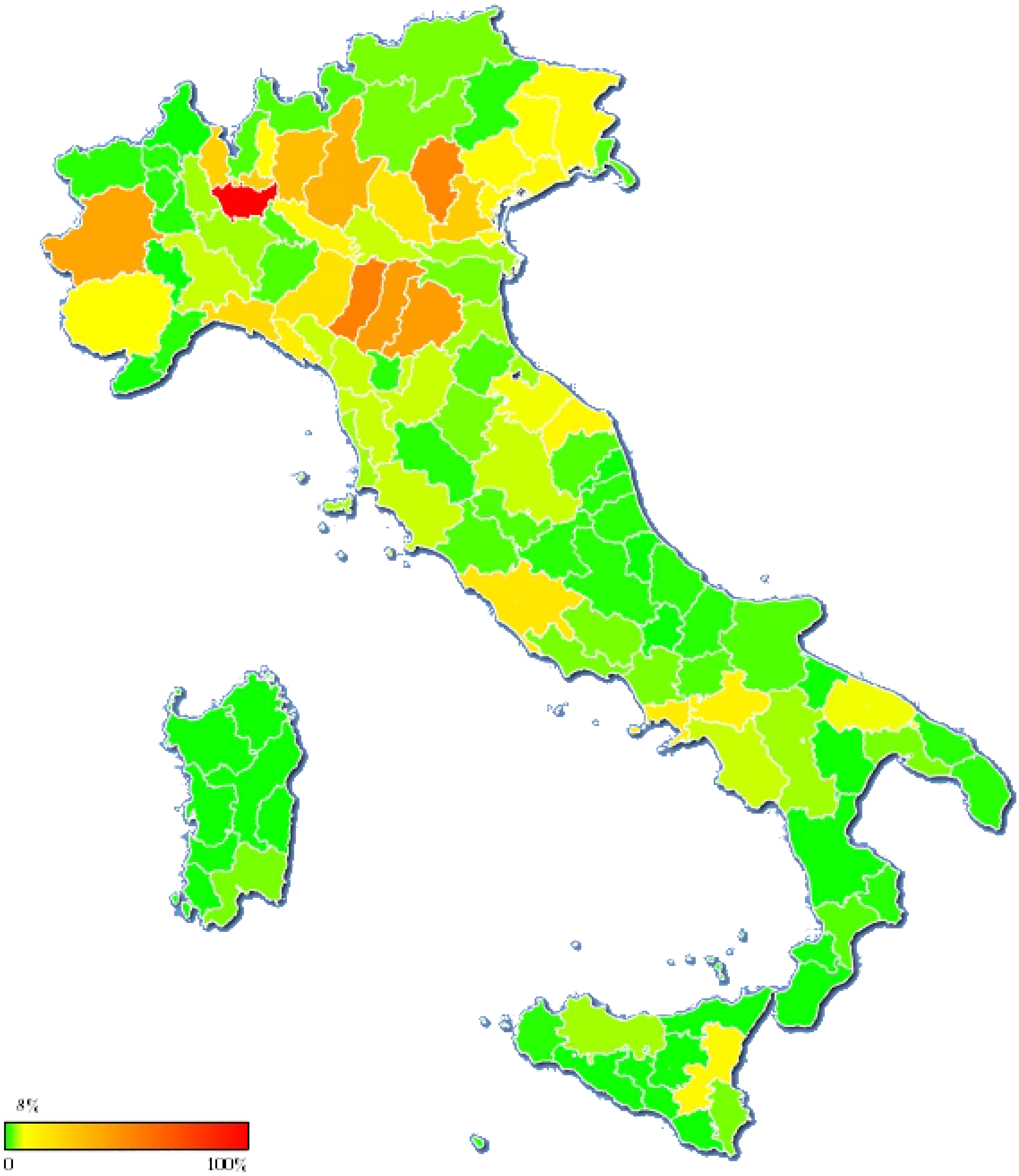


Figure C.2: Map for reference group 1.

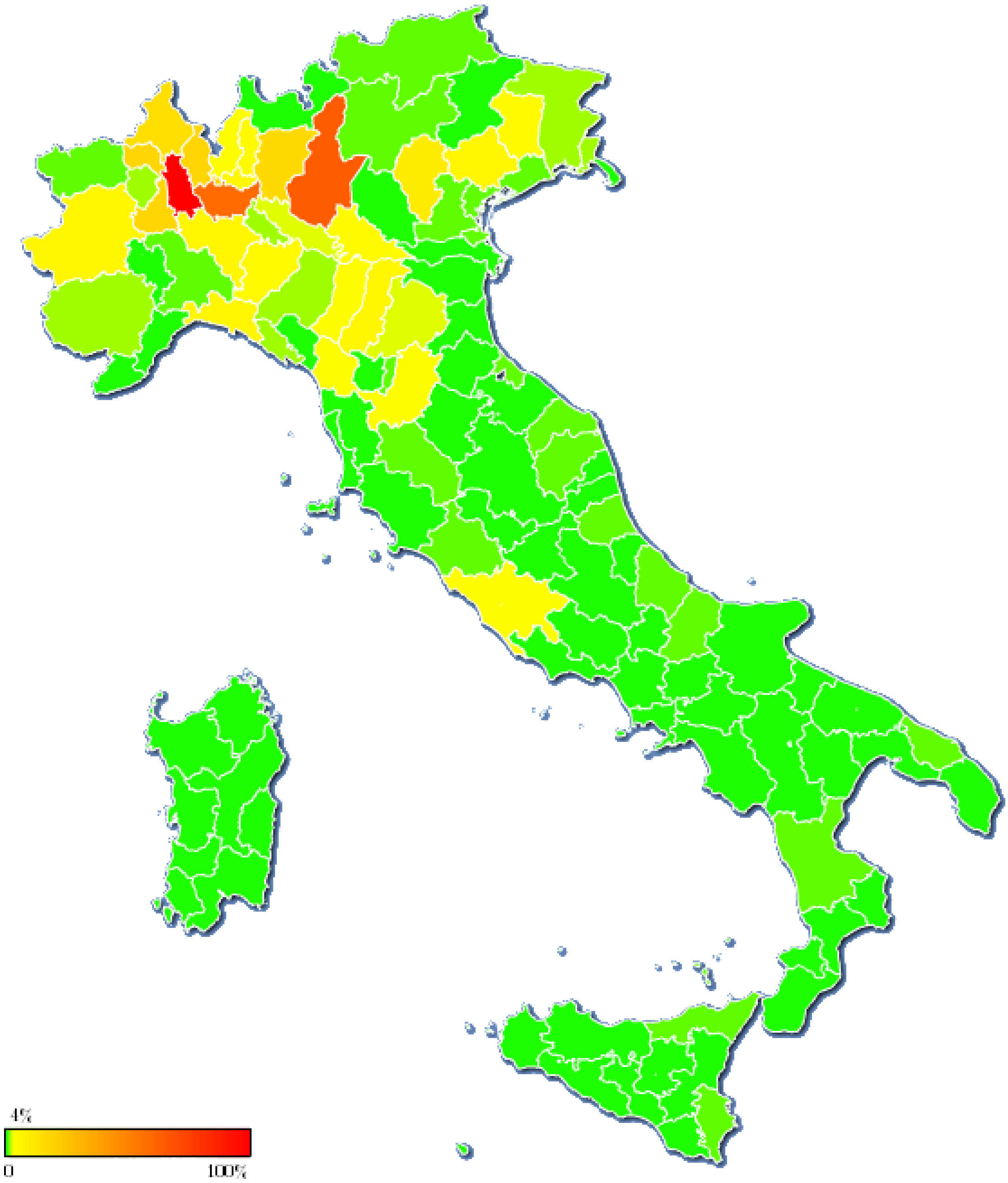


Figure C.3: Map for reference group 2.

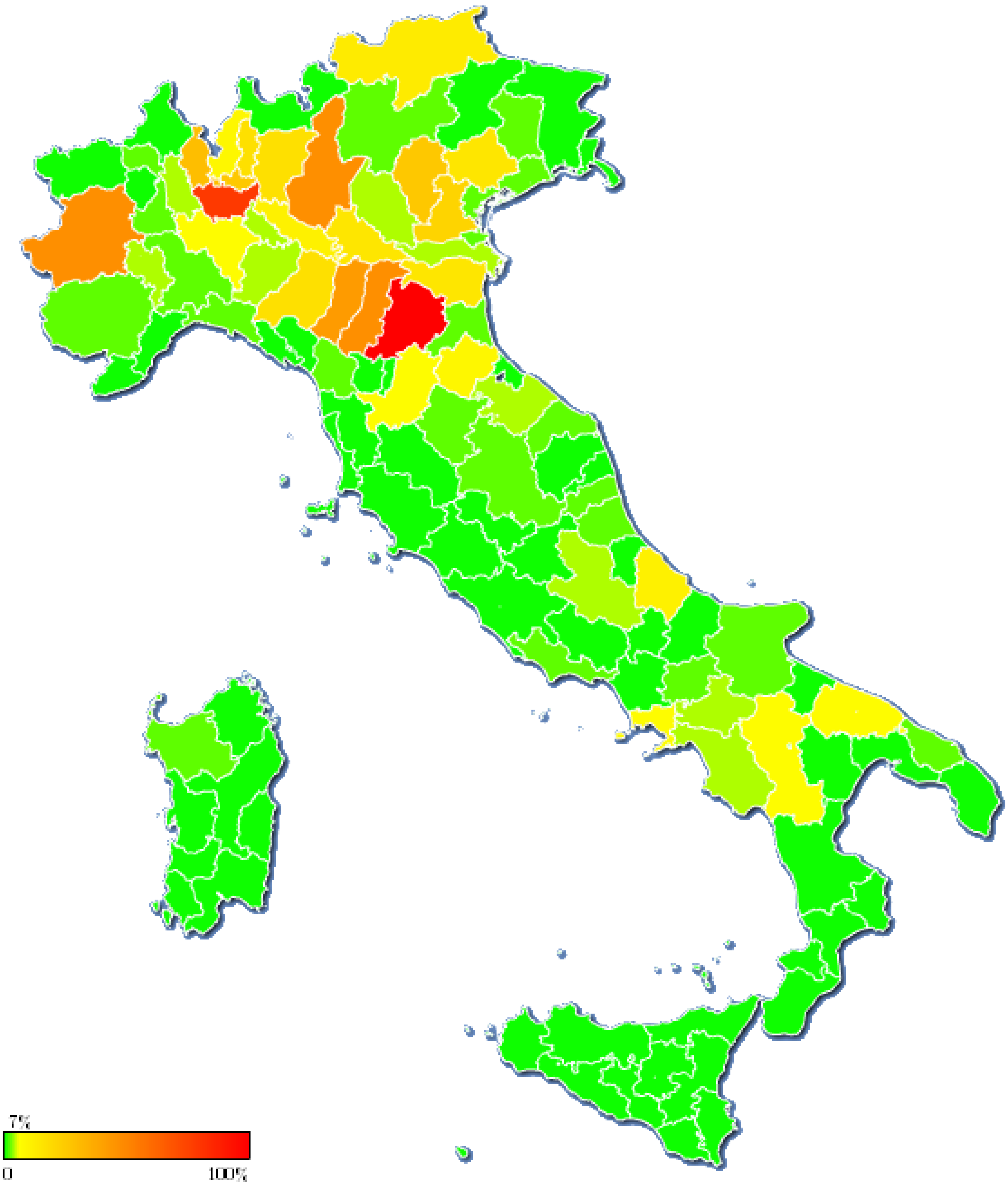


Figure C.4: Map for reference group 3.

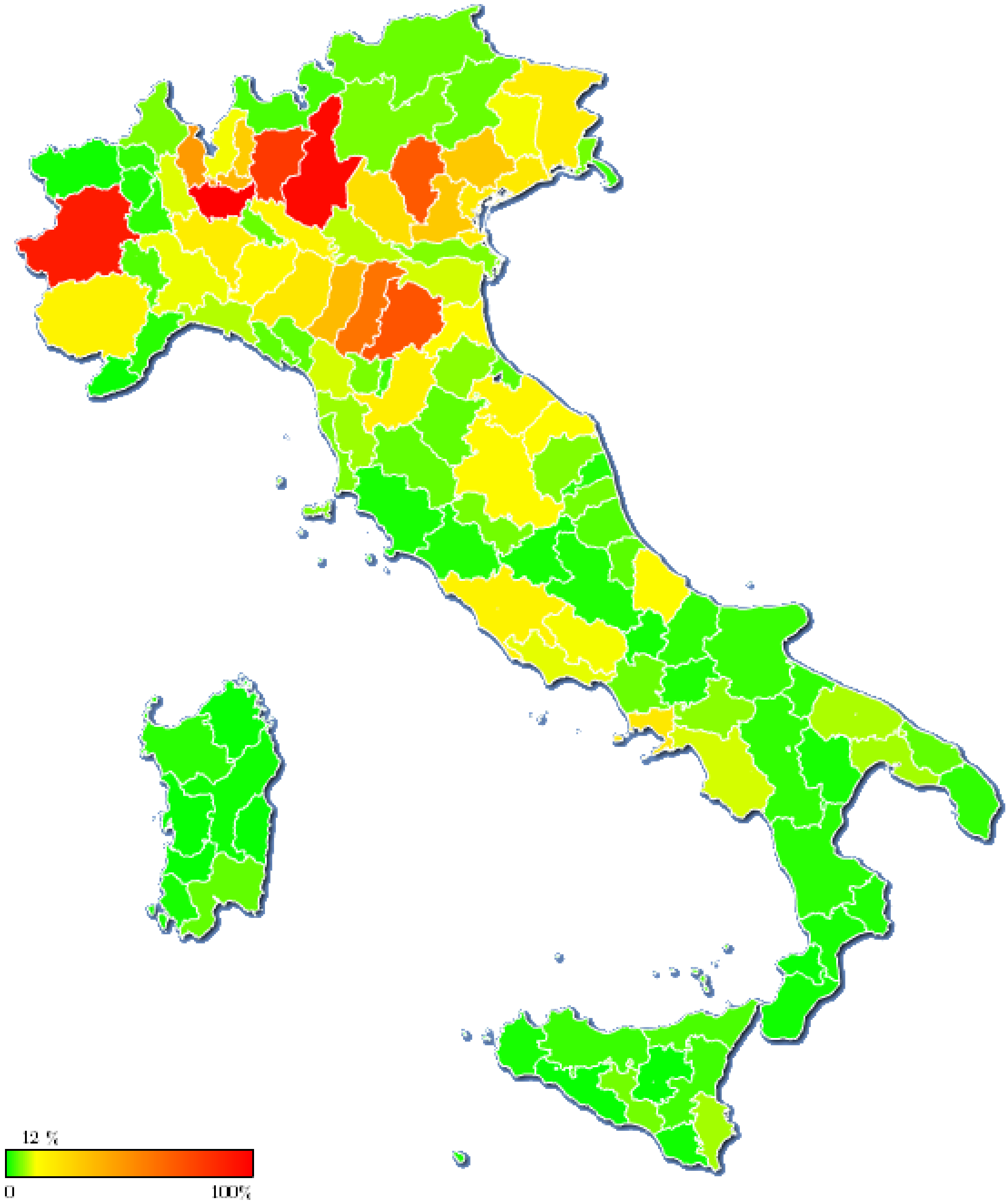


Figure C.5: Map for reference group 4.

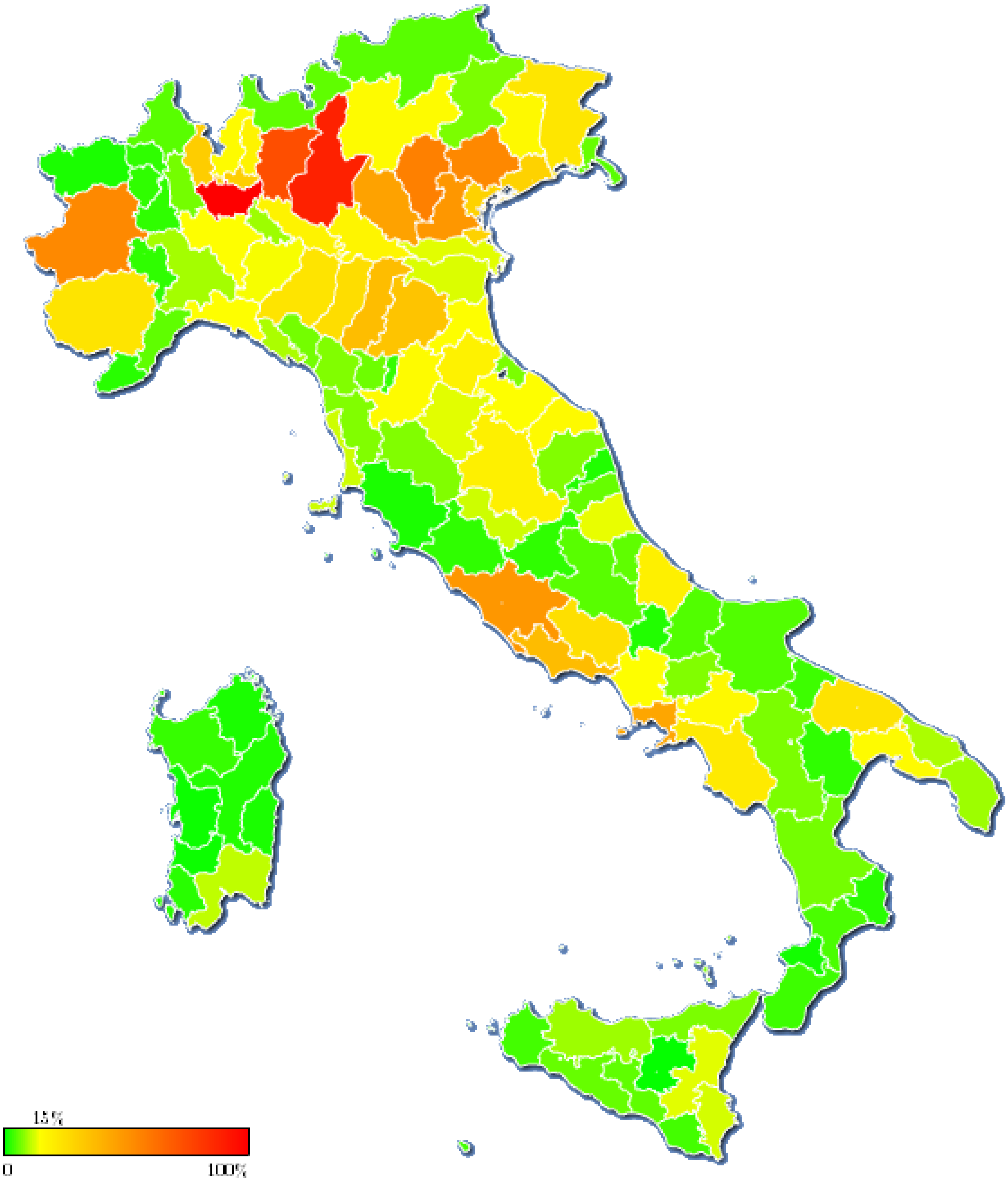


Figure C.6: Map for reference group 5.

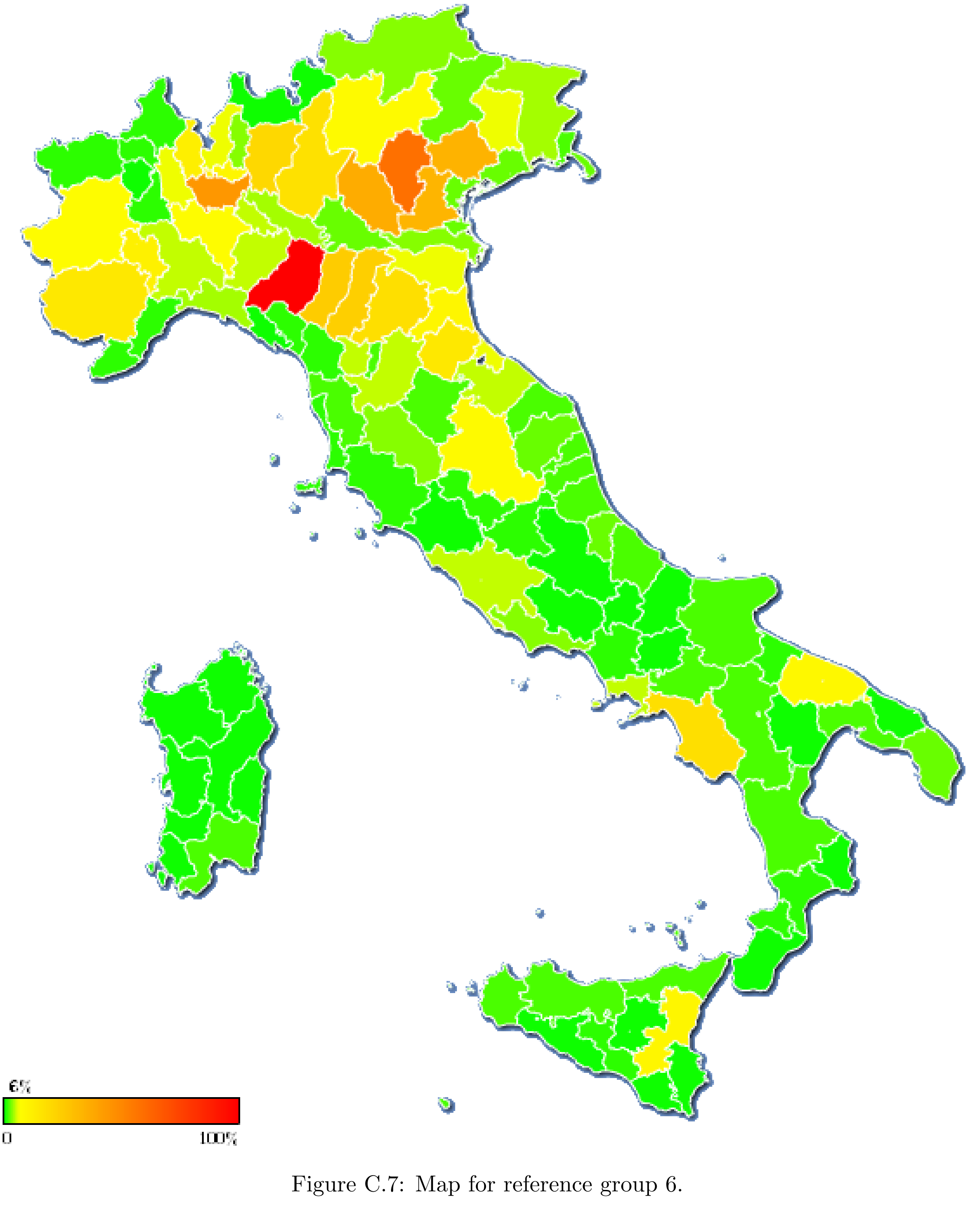


Figure C.7: Map for reference group 6.

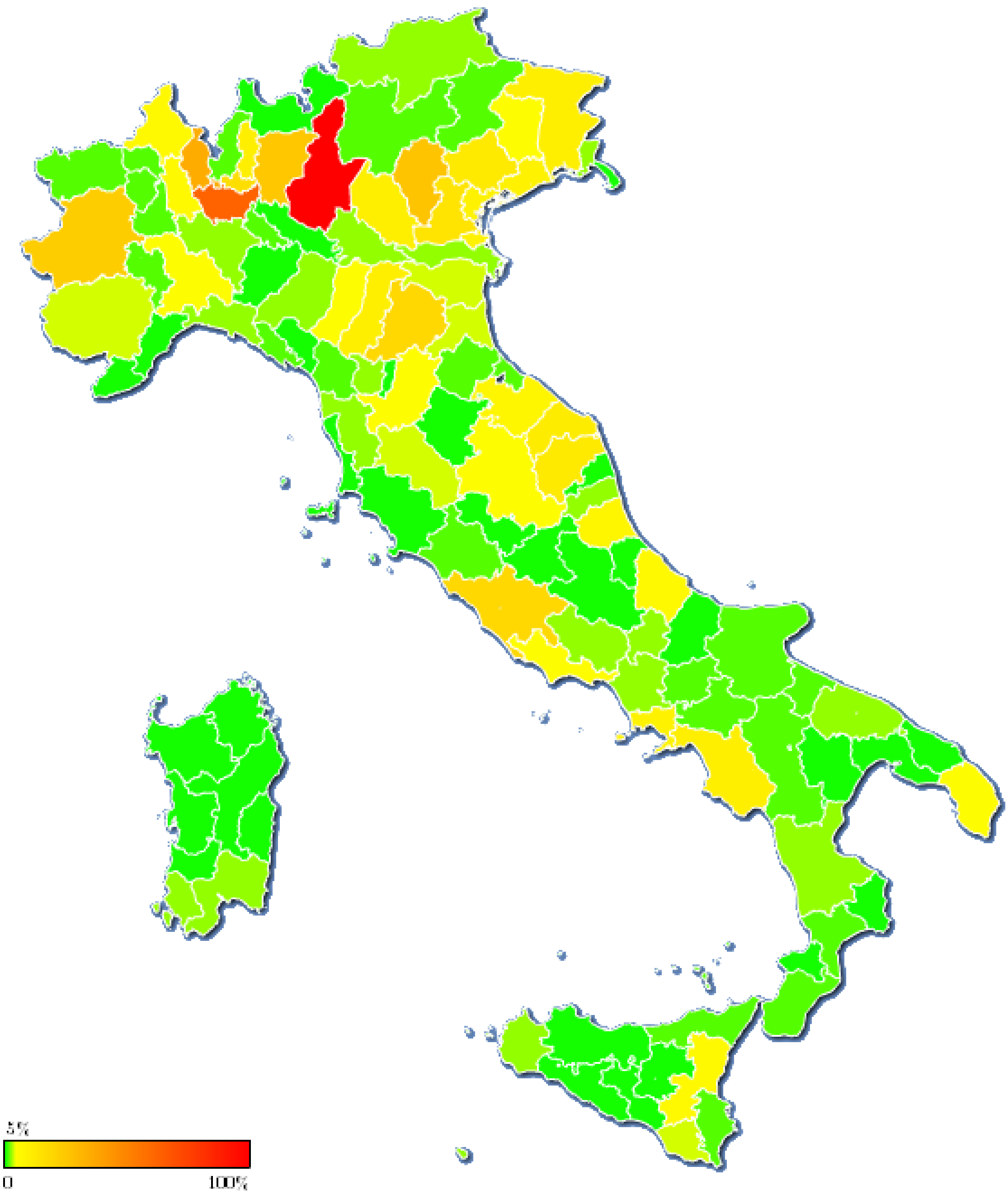


Figure C.8: Map for reference group 7.

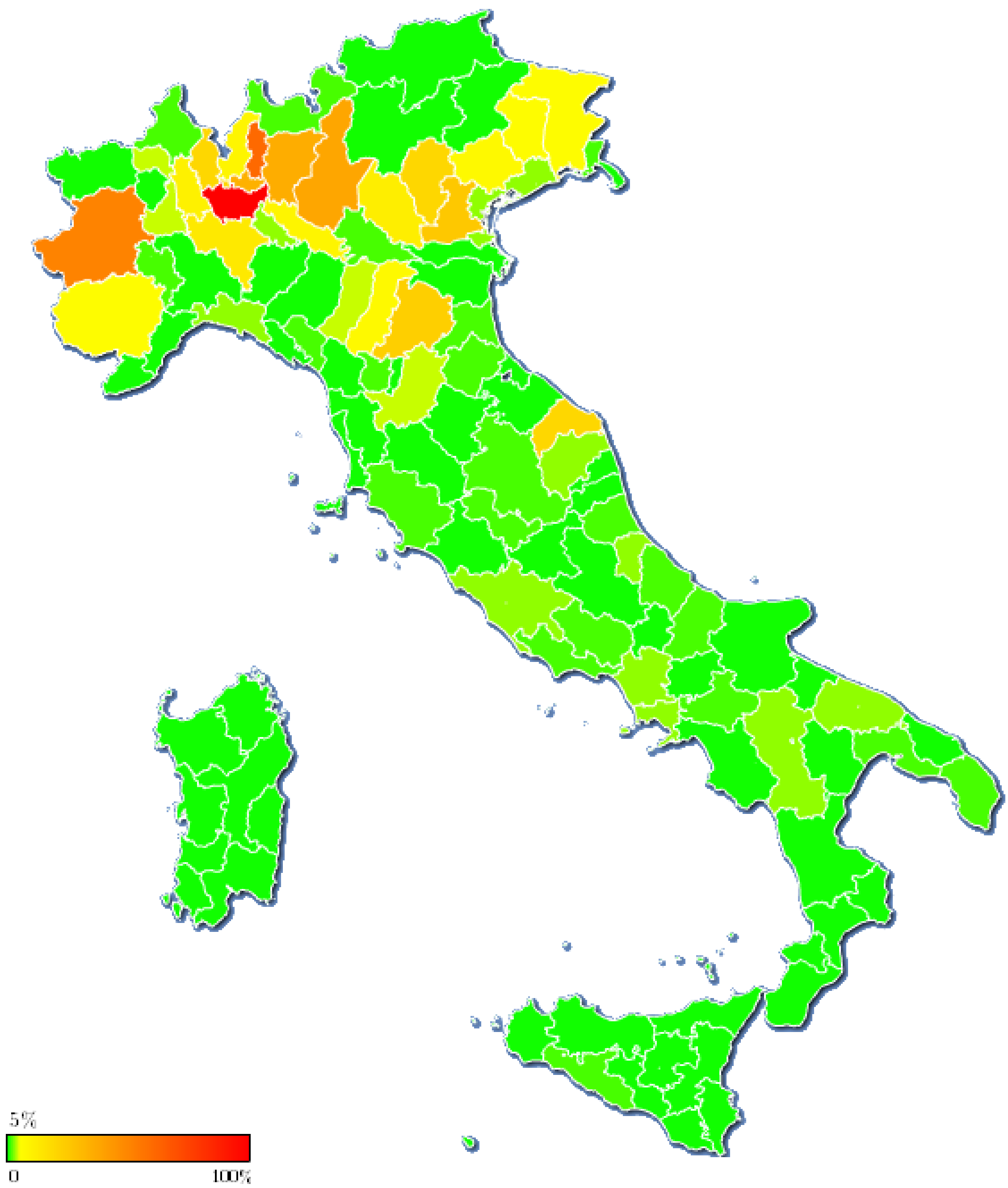


Figure C.9: Map for reference group 8.

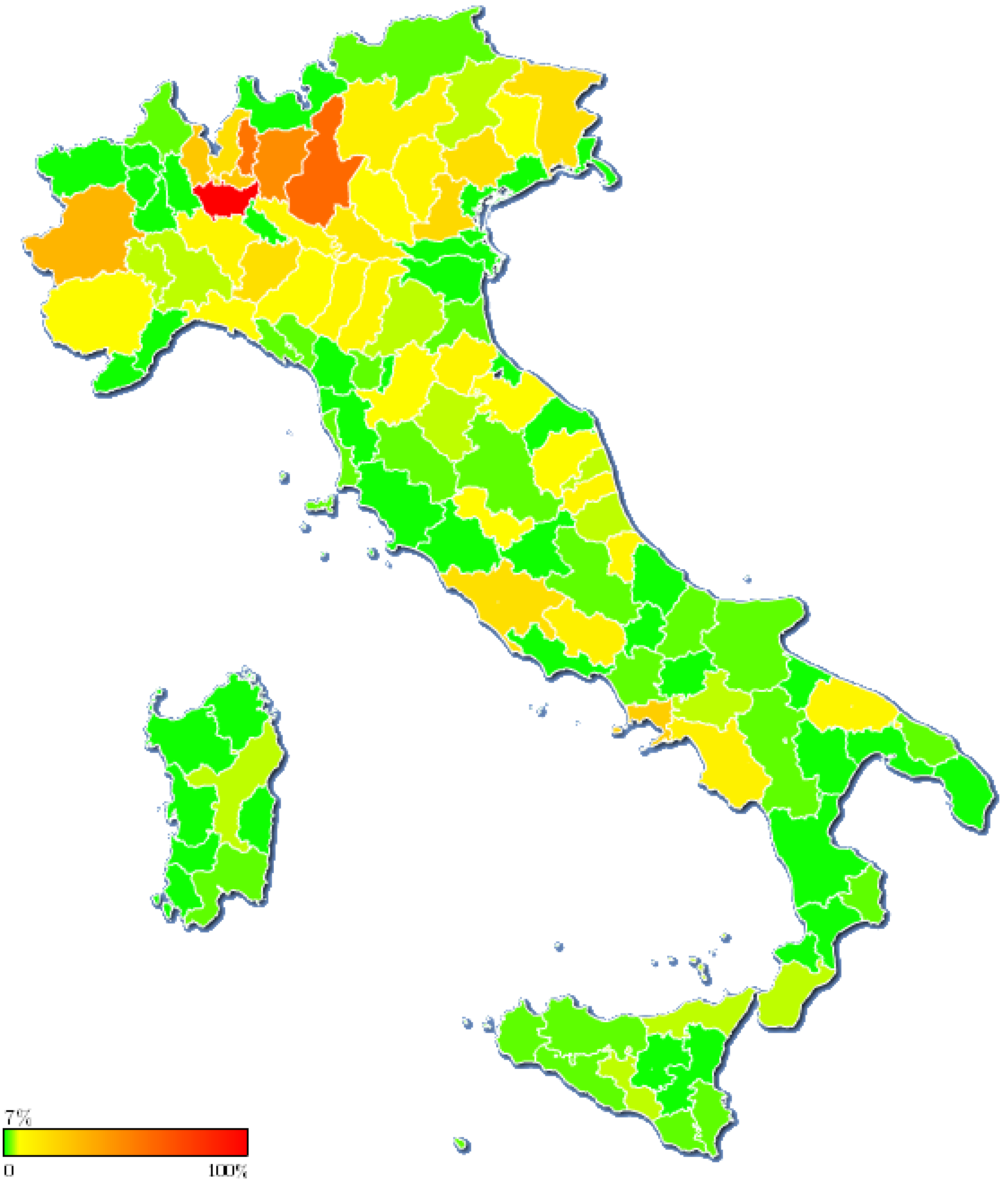


Figure C.10: Map for reference group 9.

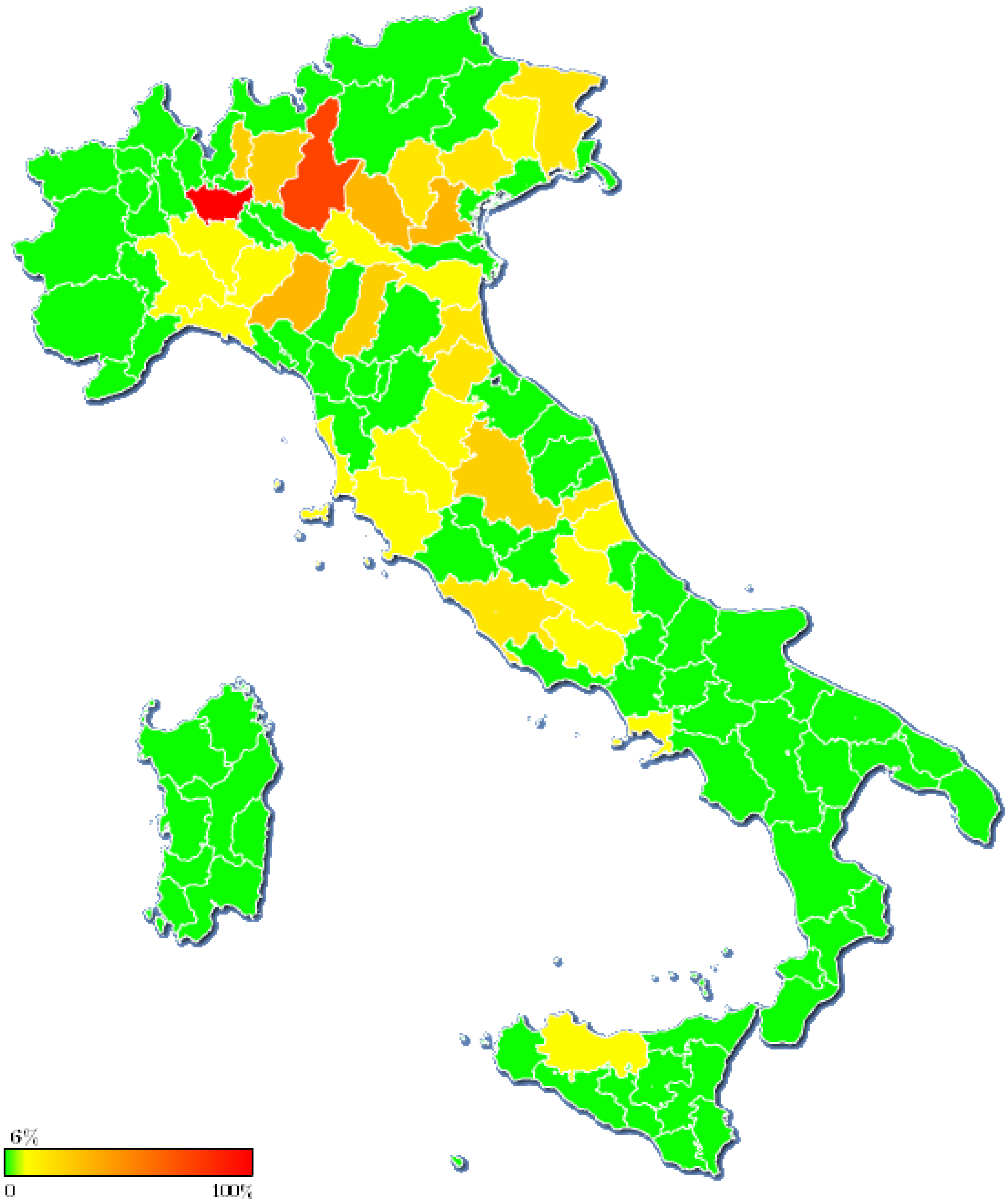


Figure C.11: Map for reference group 10.

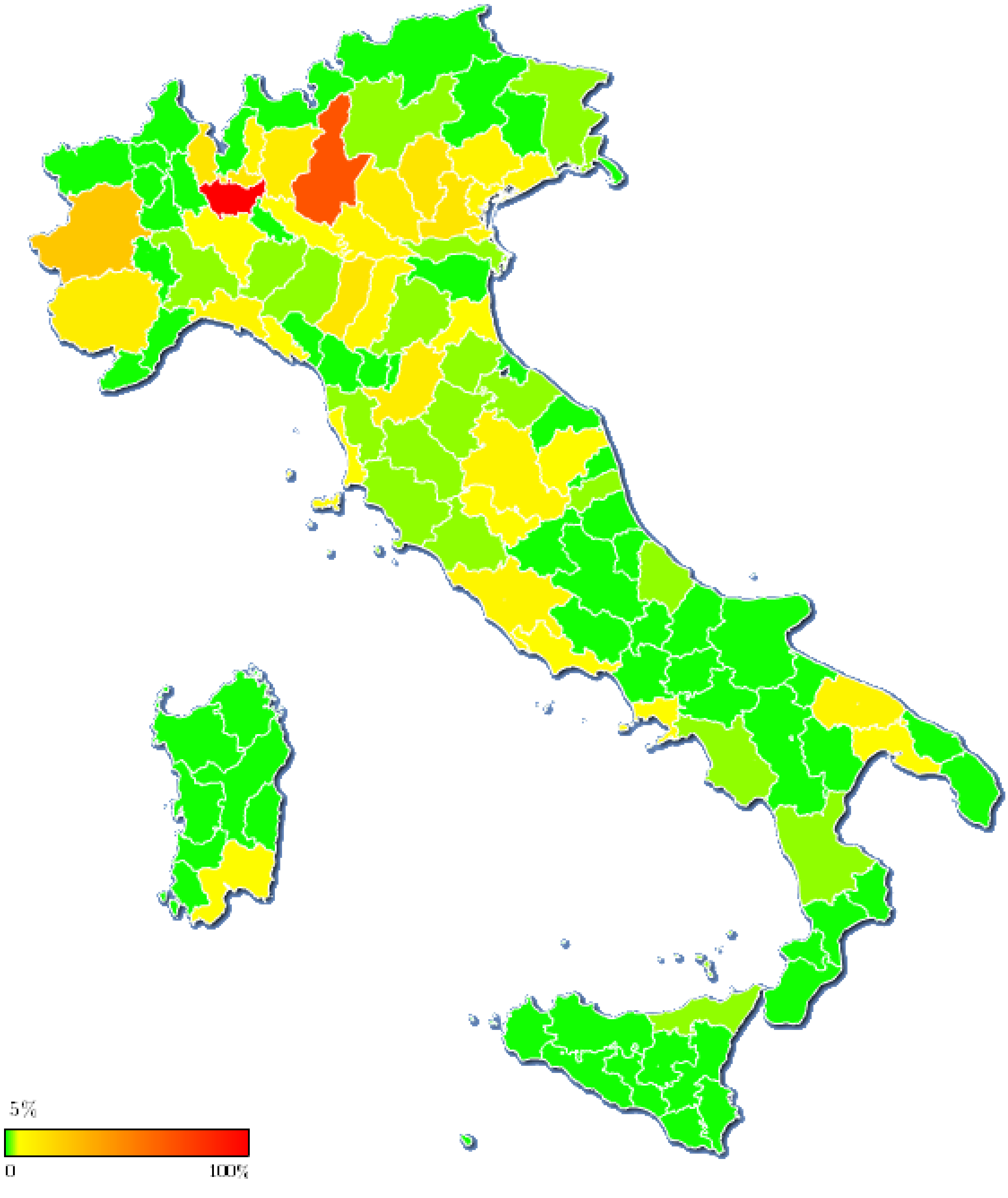


Figure C.12: Map for reference group 11.

Appendix D

SQL code for prototype database

This appendix presents the SQL code used to build the prototype described in section 3.5. The code has been develop from the relative ER model, using the apposite function of the software Open ModelSphere.

```
CREATE TABLE ARC
(
    ID1 INTEGER NOT NULL,
    VAL DECIMAL NOT NULL,
    COMPON_ID TEXT NOT NULL
);

CREATE TABLE COMPON
(
    ID2 INTEGER NOT NULL,
    NAME1 TEXT NOT NULL,
    TYPE1 INTEGER NOT NULL,
    VALUE1 DOUBLE PRECISION NULL,
    TEXT TEXT NULL
);

CREATE TABLE END_CLIENT
(
    ID6 INTEGER NOT NULL,
    NAME5 TEXT NOT NULL,
    ARC_ID2 INTEGER NOT NULL
);

CREATE TABLE EXTERN
(
    ID3 INTEGER NOT NULL,
    TYPE2 BINARY NOT NULL,
    NAME2 TEXT NULL,
    ARC_ID INTEGER NOT NULL
);

CREATE TABLE GEO.AR
(
    ID7 INTEGER NOT NULL,
    CITY TEXT NULL,
    PROVIN TEXT NULL,
    REGION TEXT NULL,
    TEXT1 TEXT NULL
```

```
);

CREATE TABLE INDICA
(
    ID5 INTEGER NOT NULL,
    NAME4 TEXT NOT NULL,
    VALUE2 DOUBLE PRECISION NOT NULL,
    UOM TEXT NOT NULL,
    METRIC TEXT NULL,
    NODE_ID INTEGER NOT NULL
);

CREATE TABLE NODE
(
    IDN INTEGER NOT NULL,
    NAME TEXT NOT NULL,
    TYPE INTEGER NOT NULL
);

    END
```

Bibliography

Supply chain guru, June 2012. URL `http://www.llamasoft.com/products-overview/supply-chain-guru/`.

Haitham Al-zu'bi. Applying electronic supply chain management using multi-agent system: A managerial perspective. *International Arab Journal of e-Technology*, 1(3), January 2010.

Christian Almeder and Margaretha Preusser. A hybrid simulation optimization approach for supply chains. In *EUROSIM*, 2007.

George A. Antaki. *Piping and Pipeline Engineering*. Marcel Dekker, 2003.

Steven Antosz. Vehicle supply chain analysis system, October 2005. URL `http://www.google.com/patents/US6952807`.

G. Azzone. *Sistemi di controllo di gestione: metodi, strumenti e applicazioni*. Etas, 2006.

A.P. Barroso, V.H. Machado, and V. Cruz Machado. Supply chain resilience using the mapping approach. In Pengzhong Li, editor, *Supply Chain Management*, chapter 7, pages 161–184. InTech, Published, 2011.

B.M. Beamon. Measuring supply chain performance. *International Journal of Operations & Production Management*, 19(3):275–292, 1999.

R. Bhagwat and M.K. Sharma. Performance measurement of supply chain management: A balanced scorecard approach. *Computers & Industrial Engineering*, 53(1):43–62, 2007.

B. Biais and C. Gollier. Trade credit and credit rationing. *Review of Financial Studies*, pages 903–937, 1997.

S. Biswas and Y. Narahari. Object oriented modeling and decision support for supply chains. *European Journal of Operational Research*, 153(3):704–726, 2004.

R. Bocconcelli and A. Pagano. La competitività delle medie imprese della meccanica strumentale: risultati della ricerca. 2011.

James G. Bralla. *Handbook of Manufacturing Processes*. Industrial Press, 2007.

Andrea Brasili, Rino Ferrata, and Gianfranco Tosini. *Clienti d'Acciaio*. Siderweb, 2011.

P.C. Brewer and T.W. Speh. Using the balanced scorecard to measure supply chain performance. *Journal of Business logistics*, 21(1):75–94, 2000.

H.J. Bullinger, M. Kühner, and A. Van Hoof. Analysing supply chain performance using a balanced measurement method. *International Journal of Production Research*, 40(15):3533–3543, 2002.

R. Calantone, C. Dröge, et al. Supply chain flexibility: an empirical study. *Journal of Supply Chain Management*, 35(3):16–24, 1999.

E. Camerinelli and A. Cantù. Measuring the value of the supply chain: A framework. *Supply Chain Practice*, 8(2):40–59, 2006.

Enrico Camerinelli. Supply chain finance. 2008.

N. Capaldi. Corporate social responsibility and the bottom line. *International Journal of Social Economics*, 32(5):408–423, 2005.

Giacomo Carcano and Stefano Ghiggeri. L'adozione dell'eprocurement nella filiera del metalmeccanico: un'analisi empirica. Tesina, Politecnico di Milano, 2005.

M. Caridi, L. Crippa, A. Perego, A. Sianesi, and A. Tumino. Measuring visibility to improve supply chain performance: a quantitative approach. *Benchmarking: An International Journal*, 17(4):593–615, 2010.

Ducnan Carmer. *Basic Statistics for Social Science*. Psychology Press, 1997.

CR Carter and M. Dresner. Environmental purchasing and supply management: cross-functional development of grounded theory. *The Journal of Supply Chain Management*, 37(3):12–27, 2001.

A. Casartelli and Matteo Somaini. eprocurement: uno schema di riferimento delle diverse strategie e dei diversi modelli. Master's thesis, Politecnico di Milano, 2004.

John Chambers, William Cleveland, Beat Kleiner, and Paul Tukey. *Graphical Methods for Data Analysis*. Wadsworth, 1983.

D.C. Chatfield, T.P. Harrison, and J.C. Hayya. Sisco: a supply chain simulation tool utilizing silk and xml. In *Proceedings of the 33nd conference on Winter simulation*, pages 614–622. IEEE Computer Society, 2001a.

D.C. Chatfield, T.P. Harrison, and J.C. Hayya. The supply chain modeling language (scml). In *Working Paper. Department of Supply Chain and Information Systems, Penn State University, University Park, PA*, 2003.

D.C. Chatfield, T.P. Harrison, and J.C. Hayya. Sisco: An object-oriented supply chain simulation system. *Decision Support Systems*, 42(1):422–434, 2006.

D.C. Chatfield, J.C. Hayya, and T.P. Harrison. A multi-formalism architecture for agent-based, order-centric supply chain simulation. *Simulation Modelling Practice and Theory*, 15(2):153–174, 2007.

D.C. Chatfield, T.P. Harrison, and J.C. Hayya. Scml: An information framework to support supply chain modeling. *European Journal of Operational Research*, 196(2):651–660, 2009.

D.C. Chatfield et al. *Sisco and scml: software tools for supply chain simulation modeling and information sharing*. The Pennsylvania State University, 2001b.

Xiangfeng Chen and Chenxi Hu. The value of supply chain finance. 2011.

J.C.P. Cheng, K.H. Law, H. Bjornsson, A. Jones, and R.D. Sriram. Modeling and monitoring of construction supply chains. *Advanced Engineering Informatics*, 24(4):435–455, 2010.

Maria Chiarvesio, Eleonora Di Maria, and Roberto Grandinotti. *Le ICT a supporto dell'innovazione aziendale*. FrancoAngeli, 2005.

W.J. Christensen, R.N. Germain, and L. Birou. Variance vs average: supply chain lead-time as a predictor of financial performance. *Supply Chain Management: An International Journal*, 12(5):349–357, 2007.

M. Christopher and H. Peck. Building the resilient supply chain. *International Journal of Logistics Management, The*, 15(2):1–14, 2004.

European Commission. Nace - statistical classification of economic activities in the european community, rev. 1.1, 2012. URL `http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_1_1&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC`.

M.C. Cooper, D.M. Lambert, and J.D. Pagh. Supply chain management: more than a new name for logistics. *International Journal of Logistics Management, The*, 8(1):1–14, 1997.

D. Cope, M.S. Fayez, M. Mollaghasemi, and A. Kaylani. Supply chain simulation modeling made easy: an innovative approach. In *Simulation Conference, 2007 Winter*, pages 1887–1896. Ieee, 2007.

Dayana Cope. *Automatic generation of supply chain simulation models from scor based ontologies.* PhD thesis, University of Central California, Spring Term 2008.

Supply Chain Council. *SCOR - Supply Chain Operations Reference Model*, version 9.0 edition, 2008.

Supply Chain Council. Supply chain definition. http://supply-chain.org/node/69, January 2012.

John J. Coyle, Edward J. Bardi, and John C. Langley. *The management of business logistics.* South-Western College Publishing, 2002.

Suresh K. Damodaran and Todd L. Margo. Supply chain visualization and management system with dynamic zooming, March 2011. URL `http://www.google.com/patents/US7900153`.

E. Paul DeGarmo, J. T. Black, and Ronald A. Kohser. *Materials and Processes in Manufacturing.* Wiley, 2007.

H. Ding, L. Benyoucef, X. Xie, C. Hans, and J. Schumacher. One a new tool for supply chain network optimization and simulation. In *Proceedings of the 36th conference on Winter simulation*, pages 1404–1411. Winter Simulation Conference, 2004.

Koray Dogan, Adeel Najmi, and Ramesh Raman. Optimizing an inventory of a supply chain, November 2004. URL `http://www.google.com/patents/US7853462`.

A. Drogoul, D. Vanbergue, and T. Meurisse. Multi-agent based simulation: Where are the agents? *Multi-agent-based simulation II*, pages 43–49, 2003.

B. Dyckman. Supply chain finance: Risk mitigation and revenue growth. *Journal of Corporate Treasury Management*, 4(2):168–173, 2011.

Y. Ebrahimy, S.M. AbouRizk, S. Fernando, and Y. Mohamed. Simphony supply chain simulator: a simulation toolkit to model the supply chain of construction projects. *Simulation*, 87(8):657–667, 2011.

P.S. Ellen, D.J. Webb, and L.A. Mohr. Building corporate associations: consumer attributions for corporate socially responsible programs. *Journal of the Academy of Marketing Science*, 34(2):147–157, 2006.

D. Estampe, S. Lamouri, J.L. Paris, and S. Brahim-Djelloul. A framework for analysing supply chain performance evaluation models. *International Journal of Production Economics*, 2010.

S.E. Fawcett, G.M. Magnan, and M.W. McCarter. Benefits, barriers, and bridges to effective supply chain management. *Supply Chain Management: An International Journal*, 13(1):35–48, 2008.

M. Fayez, L. Rabelo, and M. Mollaghasemi. Ontologies for supply chain simulation modeling. In *Simulation Conference, 2005 Proceedings of the Winter*, pages 7–pp. IEEE, 2005.

M. Fayez, D. Cope, A. Kaylani, M. Callinan, E. Zapata, and M. Mollaghasemi. Earth to orbit logistics and supply chain modeling and simulation for nasa exploration systems. In *Simulation Conference, 2006. WSC 06. Proceedings of the Winter*, pages 1462–1469. IEEE, 2006.

Mohamed S. Fayez. *An automated methodology for a comprehensive definition of the supply chain using generic ontological components.* PhD thesis, University of Central California, Spring Term 2005.

Giovanni Ferri and Marco Ventura. Sui benefici della rispecializzazione dei distretti industriali nei macchinari del made in italy. 2007.

S. Ganesan, M. George, S. Jap, R.W. Palmatier, and B. Weitz. Supply chain management and retailer performance: Emerging trends, issues, and implications for research and practice. *Journal of Retailing*, 85(1):84–94, 2009.

C. Thomsen Giménez and H. Ramalhinho Dias Lourenço. E-supply chain management: Review, implications and directions for future research. *UPF Economics and Business Working Paper 769*, 2004.

G. Giovannetti, G. Scanagatta, N. Boccella, L. F. Signorini, and G. Mion. Le metodologie di misurazione dei distretti industriali. Commissione per la garanzia dell'informazione statistica, Presidenza del consiglio dei ministri, 2005.

C. Gopal, J. Kamauff, W. Partsch, and G. Tyndall. Supercharging supply chains. 1998.

M. Grossman. The role of trust and collaboration in the internet-enabled supply chain. *Journal of American Academy of Business*, 5(1/2):391–396, 2004.

F. Gryna. Supply chain management, quality planning and analysis, 2001. chapter 15.

A. Gunasekaran, C. Patel, and E. Tirtiroglu. Performance measures and metrics in a supply chain environment. *International journal of operations & production Management*, 21(1/2):71–87, 2001.

H. N. Gupta, R. C. Gupta, and Arun Mittal. *Manufacturing Processes*. New Age International Publisher, 2009.

Alexandros Haristos and Gianni Guglielmetti. L'esupply chain nelle pmi dei settori tessile-abbigliamento e metalmeccanico. Master's thesis, Politecnico di Milano, 2005.

W. R. Hartely-Urquhart. Supply chain financing system and method, Dec 2000. URL `http://www.google.com/patents/US6167385`.

Dennis R. Heldman and Daryl B. Lund. *Handbook of food engineering*. 2007.

E. Hofmann. Supply chain finance-some conceptual insights. *Logistik Management. Innovative Logistikkonzepte. Wiesbaden: Deutscher Universitäts-Verlag*, pages 203–214, 2005.

E. Hofmann and O. Belin. *Supply Chain Finance Solutions: Relevance-Propositions-Market Value*. Springer Verlag, 2011.

S.H. Huan, S.K. Sheoran, and G. Wang. A review and analysis of supply chain operations reference (scor) model. *Supply Chain Management: An International Journal*, 9(1):23–29, 2004.

G.Q. Huang, XY Zhang, and L. Liang. Towards integrated optimal configuration of platform products, manufacturing processes, and supply chains. *Journal of Operations Management*, 23(3):267–290, 2005a.

G.Q. Huang, X.Y. Zhang, and V.H.Y. Lo. Optimal supply chain configuration for platform products: impacts of commonality, demand variability and quantity discount. *International Journal of Mass Customisation*, 1(1):107–133, 2005b.

American Law Institute. *Uniform Commercial Code*, volume 5-102. National Conference of Commissioners on Uniform State Laws, 2001.

C.A. Jacobs. Operations management for competitive advantage, 2004.

Iris Jensen. The leontief open production model or input-output analysis. December 2001.

R.S. Kaplan and D.P. Norton. The balanced scorecard–measures that drive performance. *Harvard business review*, 70(1):71–79, 1992.

David W Kelton, Randall P. Sadowski, and Nancy B. Swets. *Simulation with Arena*. McGraw-Hill, 5th edition, 2010.

R.D. Klassen and C.P. McLaughlin. The impact of environmental management on firm performance. *Management science*, pages 1199–1214, 1996.

J.P.C. Kleijnen. Supply chain simulation tools and techniques: a survey. *International Journal of Simulation and Process Modelling*, 1(1):82–89, 2005.

J.P.C. Kleijnen and M.T. Smits. Performance metrics in supply chain management. *Journal of the Operational Research Society*, pages 507–514, 2003.

B.J. La Londe and J.M. Masters. Emerging logistics strategies: blueprints for the next century. *International Journal of Physical Distribution & Logistics Management*, 24(7):35–47, 1994.

O. Labarthe, B. Espinasse, A. Ferrarini, and B. Montreuil. Toward a methodological framework for agent-based modelling and simulation of supply chains in a mass customization context. *Simulation Modelling Practice and Theory*, 15(2):113–136, 2007.

D.M. Lambert, J.R. Stock, and L.M. Ellram. *Fundamentals of logistics management*. Irwin/McGraw-Hill Chicago, IL., 1998.

Jean-François Lamoureux and Todd Evans. Supply chain finance: a new means to support the competitiveness and resiliance of global value chain. 2011.

S. Lancaster, D.C. Yen, and C.Y. Ku. E-supply chain management: an evaluation of current web initiatives. *Information management & computer security*, 14(2):167–184, 2006.

D. Lanier, W.F. Wempe, and Z.G. Zacharia. Concentrated supply chain membership and financial performance: Chain-and firm-level perspectives. *Journal of Operations Management*, 28(1):1–16, 2010.

L. Lapide. What about measuring supply chain performance? *Achieving Supply Chain Excellence Through Technology*, 2:287–297, 2000.

C.H. Lee and B.D. Rhee. Trade credit for supply chain coordination. *European Journal of Operational Research*, 2011.

H.L. Lee. Aligning supply chain strategies with product uncertainties. *California management review*, 44(3):105–119, 2002.

H.L. Lee, V. Padmanabhan, and S. Whang. The bullwhip effect in supply chains1. *Sloan management review*, 38(3):93–102, 1997.

W. Leontief. *Input-output economics*. Oxford University Press, USA, 1986.

J. Liu, W. Wang, Y. Chai, and Y. Liu. Easy-sc: a supply chain simulation tool. In *Proceedings of the 36th conference on Winter simulation*, pages 1373–1378. Winter Simulation Conference, 2004.

A.C. Lyons, A.E.C. Mondragon, F. Piller, and R. Poler. Modelling and simulating supply chains. In *Customer-driven supply chains*, pages 113–131. Springer, 2012.

C.R. Mainardi, M. Salva, and M. Sanderson. Label of origin: Made on earth. *STRATEGY AND BUSINESS*, pages 42–53, 1999.

R. Mann. The role of letters of credit in payment transactions. *Michigan Law Review*, 99:2494, 2000.

I. Manuj, J.T. Mentzer, and M.R. Bowers. Improving the rigor of discrete-event simulation in logistics and supply chain research. *International Journal of Physical Distribution & Logistics Management*, 39(3):172–201, 2009.

P. Margnini and C. Gilodi. La meccanica strumentale: caratteristiche, comportamenti e strategie. ex-machina: il caso varesino. 2009.

A. Meca and JB Timmer. Supply chain collaboration. 2007.

J.T. Mentzer, W. DeWitt, J.S. Keebler, S. Min, N.W. Nix, C.D. Smith, and Z.G. Zacharia. Defining supply chain management. *Journal of Business logistics*, 22(2):1–25, 2001.

HE Merrill. A technique for comparative analysis of kiviat graphs. *ACM SIGMETRICS Performance Evaluation Review*, 3(1):34–39, 1974.

D. Mollenkopf, D. Closs, D. Twede, S. Lee, and G. Burgess. Assessing the viability of reusable packaging: a relative cost approach. *Journal of Business Logistics*, 26(1):169–197, 2005.

C. Morgan. Structure, speed and salience: performance measurement in the supply chain. *Business Process Management Journal*, 10(5):522–536, 2004.

M.F. Morris. Kiviat graphs: conventions and figures of merit. *ACM SIGMETRICS Performance Evaluation Review*, 3(3):2–8, 1974.

A. Nagurney and F. Toyasaki. Supply chain supernetworks and environmental criteria. *Transportation Research Part D: Transport and Environment*, 8(3):185–213, 2003.

Mohinder L. Nayyar. *Piping Handbook*. McGraw-Hill, 2000.

Yan Ni-Na. Optimal stekelemburg strategy for supply chain finance with credit limit. 2011.

Mark Norris and Steve West. *eBusiness Essentials: Technology and network requirements for mobile and online markets*. John Wiley& sons Inc, 2002.

University of Modena and Reggio Emilia. Metalnet, struttura e dinamica dei cambiamenti nelle relazioni tra le imprese metalmeccaniche. http://www.metalnet.unimore.it, January 2012.

J.H. Park, J.K. Lee, and J.S. Yoo. A framework for designing the balanced supply chain scorecard. *European Journal of Information Systems*, 14(4):335–346, 2005.

S.H. Park and G.R. Ungson. Interfirm rivalry and managerial complexity: A conceptual framework of alliance failure. *Organization Science*, pages 37–53, 2001.

Ronal K. Pearson. *Mining Imperfect Data: Dealing with Contamination and Incomplete Records*. SIAM, 2005.

A. Perego and P. Catti. Oltre la fattura - osservatorio "fatturazione elettronica e dematerializzazione". Technical report, School of Management, Politecnico di Milano, July 2011.

M.A. Petersen and R.G. Rajan. Trade credit: theories and evidence. *Review of Financial Studies*, 10 (3):661–691, 1997.

H.C. Pfohl and M. Gomm. Supply chain finance: optimizing financial flows in supply chains. *Logistics Research*, 1(3):149–161, 2009.

Steven G. Powell. Leading the spreadsheet revolution, 1997. URL `http://www.orms-today.org/orms-12-97/issuesineducation.html`.

Puglisi, Vicari, and Ferrillo. Classificazione delle attività economiche ateco 2002. Technical report, Istat, 2003.

N. R. Srinivasa Raghavan and Vinit Kumar Mishra. Short term financing in a cash constrained supply chain. 2009.

W.S. Randall and M.T. Farris II. Supply chain financing: using cash-to-cash variables to strengthen the supply chain. *International Journal of Physical Distribution & Logistics Management*, 39(8):669–689, 2009.

Alvin C. Rencher. Interpretation of canonical discriminant functions, canonical variates, and principal components. 1992.

John Jr. Robbins Bush. System and method for displaying logistics information associated with a supply chain, November 2002. URL `http://www.google.com/patents/US6486899`.

Warren M. Rohsenow, James P. Hartnett, and Young I. Cho. *Handbook of heat transfer*. 1998.

M.D. Rossetti and H.T. Chan. Supply chain management simulation: a prototype object-oriented supply chain simulation framework. In *Proceedings of the 35th conference on Winter simulation: driving innovation*, pages 1612–1620. Winter Simulation Conference, 2003.

Peter J. Rousseeuw and Annick M. Leroy. *Robust Regression and Outlier Detection*. Wiley, 1987.

Margherita Russo, Elena Pirani, and Sandra Paterlini. L'industria meccanica in italia: un'analisi cluster delle differenze territoriali. 2006.

George D. Saravacos and Athanasios E. Kostaropoulos. *Handbook of Food Processing Equipment*. 2005.

Sarah D. Scalet. Supply chain management guru hau lee on demand forecasting. http://cio.com/article/30381/Supply_Chain_Management_Guru_Hau_Lee_on_Demand_Forecasting, July 2001.

S. Seuring and M. Müller. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of cleaner production*, 16(15):1699–1710, 2008.

J.H. Sheridan and S. Leibs. Managing the chain. *Industry Week*, 284:50–2, 1999.

Jonathon Shlens. A tutorial on principal components analysis. 2005.

Linsday I. Smith. A tutorial on principal components analysis. 2002.

D. Stapleton, J.B. Hanna, S. Yagla, J. Johnson, and D. Markussen. Measuring logistics performance using the strategic profit model. *International Journal of Logistics Management, The*, 13(1):89–107, 2002.

L. Stemmler and S. Seuring. Finanzwirtschaftliche elemente in der lieferkettensteuerung. erste u¨ berlegungen zu einem konzept des supply chain finance. 2003.

G.C. Stevens. Integrating the supply chain. *International Journal of Physical Distribution & Logistics Management*, 19(8):3–8, 1989.

James R Stock and Douglas M. Lambert. *Strategic Logistics Management*. 4th edition, 2001.

D. Tapscott. Rethinking strategy in a networked world (or why michael porter is wrong about the internet). *Strategy and Business*, pages 34–41, 2001.

S. Terzi and S. Cavalieri. Simulation in the supply chain context: a survey. *Computers in industry*, 53 (1):3–16, 2004.

Carlo Vercellis. *Business Intelligence*. Wiley, 2009.

Vicari, Ferrillo, and Valery. Classificazione delle attività economiche ateco 2007. Technical report, Istat, 2009.

S.K. Vickery, J. Jayaram, C. Droge, and R. Calantone. The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships. *Journal of operations management*, 21(5):523–539, 2003.

S.M. Wagner, P.T. Grosse-Ruyken, and F. Erhun. The link between supply chain fit and financial performance of the firm. *Journal of Operations Management*, 2012.

ASTER workgroup. Hi-mech: distretto per l'alta tecnologia meccanica. 2003.

Ivano Wouters, Albert Nava, and Rino Ferrata. *L'acciaio diventa software*. Siderweb, 2010.

Yaqun Xu and Haiyan Zhong. Analyzing innovative model of the small and medium enterprise financing: Supply chain financing. 2011.

M. S. Yablonski, Jr. J. R. Bush, J. R. Wilson, and W. J. Debetaz. System and method for visually representing a supply chain, June 2003. URL `http://www.google.com/patents/US6577304`.

Lili Zhang and Guangle Yan. The complex economic system of supply chain financing. 2009.

Databases, manuals, and authorless technical reports

Flow charts. Technical report, ECMA - European Computer Manufacturing Association, 1966.

Flowcharting techniques. Technical report, IBM, 1985.

4°rapporto sull'industria metalmeccanica. Pubblicazione dell'osservatorio paritetico nazionale, Federmeccanica, 2001.

L'italia nell'economia internazionale, rapporto 2010/2011. Rapporto annuale ice, Istat, 2011.

Bilanci d'acciaio. Analisi in chiave strategica e prospettica dei bilanci 2010, Siderweb, 2011.

Il sistema delle tavole input-output, October 2011. URL http://www.istat.it/it/archivio/3646.

Aida database, 2011-2012. URL http://aida.bvdep.com.

Datawarehouse di statistiche sul commercio estero, January 2012. URL http://www.coeweb.istat.it/.

Supply chain guru, June 2012. URL http://www.llamasoft.com/products-overview/supply-chain-guru/.

Anylogic documentation and resources, June 2012. URL http://www.xjtek.com/anylogic/resources/documentation/.

TIBCO Businss Studio, Process Modeling User Guide, 2012.

Distretti e SSL. 8°censimento generale dell'industria e dei servizi. Distretti industriali e sistemi locali del lavoro 2001, Istat, 2001.

Statistics on the trading of goods - User guide. Eurostat, 2006.

Eurostat statistic database,. Eurostat, international trade statistics, July 2012. URL http://epp.eurostat.ec.europa.eu/newxtweb/.

ARIS Manual. Software AG, June 2012.